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SILICON CHIP

Introducing:

The Majestic

Quite Simply, THE BEST D-I-Y Speaker System ever published . . . anywhere!

JUNE 2014
ISSN 1030-2662
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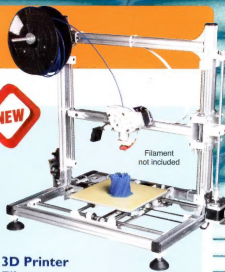
http://bit.ly/TL-4020

NEW



3D Printer Controller Module

Allows you to operate your TL-4020 without a PC! Features an SD card slot for file loading, pre-assembled but cable connection requires soldering.

TL-4022

Note: You will still require a PC to slice and prepare the 3D file.

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NEW

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SL-3457

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Publisher's Letter

Is a large loudspeaker an anachronism?

This month, we have gone out on a limb and published details of a large hifi loudspeaker system. Might it be an anachronism? Well possibly, given that the vast majority of the population are never exposed to really high quality sound and most are not interested anyway. The majority of people who do listen to music do so from MP3 recordings via those ubiquitous white-corded thingies hanging from their ears while they walk, jog or travel on public transport. And those who don't listen with ear buds probably listen in their cars. Either way, it is far from the best listening experience.

This is a marked change from about 30 years ago when the many homes had a hifi stereo system, usually with a turntable, FM/AM tuner and a Dolby tape deck. Nowadays, such a system would be based around a high-quality CD player but most homes don't have them, being more likely to have a tiny console which can play MP3 files, with questionable sound quality. Sadly, very few people are ever exposed to unamplified music so they have no benchmark to compare with the recorded music they listen to. They simply don't know what they are missing! In fact, these days about the only time that people are ever exposed to unamplified music is when they attend a classical music performance. How many people do that?

All of which means that few people have any concept of what high-fidelity sound reproduction is. Fewer still will ever have the means to obtain the necessary equipment. Over the years, SILICON CHIP has produced a number of high-quality amplifiers which have been very popular but we have never produced a really high-quality loudspeaker to match. Now we have the Majestic, as described in the article starting on page 22.

As stated in the article, it has a bass response down to 20Hz and below. That is literally unheard of these days. Why would you want it? Well, how else will you hear the lowest fundamental frequencies produced by a pipe organ (with a 32-foot pipe) or a Bosendorfer grand piano (with a 97-note keyboard) or even a tuba? But even if you don't listen to pipe organs, the typical loudspeaker really doesn't do justice to the bass output of most large stringed instruments, including a harp. How many people have heard the bass output of a harp? It is impressive.

Not only that, the Majestic is very efficient, so it does not need a high-powered amplifier to drive it to very loud levels in the average lounge room. If you do have a big amplifier, it would enable a pair of Majestics to easily fill a large auditorium.

So why is it so big? If you want a really wide-range loudspeaker with very good low-frequency response this is the only way to do it. Small drivers in small boxes cannot produce really low frequency sounds. That is why home-theatre systems usually have a sub-woofer. But the vast majority of sub-woofers cannot produce any output below about 35Hz, are usually quite inefficient and need a big amplifier to drive them. And if you have a system with a subwoofer, the chances that you have a flat response down to very low bass is, well, almost zero.

So we have produced what is superficially a large bass-reflex system which looks similar to those large systems that were popular way back in the 1950s and 1960s. Now you can see why it may be an anachronism. But it works. It is very efficient, has very wide range and has low distortion. And it is much better than any speaker system produced in those days of yore.

Apart from that, its bulk has another advantage. Unlike a tower system, it can never be tipped over by toddlers. Even so, it takes up little more floor space than a typical tower loudspeaker system or smaller systems sitting on ugly stands. To be frank, you do need a reasonably large living room but if you have a home-theatre system you probably already have the space.

If so, you can build a stereo pair of Majestics and dispense with your dodgy home-theatre speakers and subwoofer. You will be amazed at the difference.

Leo Simpson

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Google patents are a good source of information

I image that SILICON CHIP staff would check that projects do not infringe patents and that they would be familiar with searching patent records. If not, I would like to bring your attention to the wealth of information that exists in them.

In my previous occupation, I would occasionally be required to examine patents for infringement etc. Even although I can read legal jargon with relative ease, it has to be one of the most tedious and boring exercises.

When I began developing my service robot, I wanted to make sure that I would not be sued by a patent holder. Consequently, I began searching the web for patents on subjects associated with the robot. I discovered that Google has a large repository of patents which can be freely viewed and downloaded.

There are patents on almost everything but obviously the electronic ones would be of most interest to readers of SILICON CHIP. Patent holders describe in good detail how their idea works and this is great when one is looking for a solution to a problem. If the patent has been issued before 1994, then it has expired and the idea is free for use (patents currently last for 20 years.)

Google has made the search for ideas relatively easy. Each patent is given a web page and on the page are links to view and download PDF copies. There are also links to other patents which are cited by the current patent and which reference the current patent. These links open up a whole world of related patents and ideas.

If anyone is interested, here are three patents which illustrate the information available:

www.google.com/patents/US4807712
www.google.com/patents/US4926170
www.google.com/patents/US5463384

NB: it will be necessary to view or download the PDF of the patent in order to be able to read the diagrams and circuits.

George Ramsay,
Holland Park, Qld.

Comment: while we independently develop our projects and circuits, SILICON CHIP does not have the resources to thoroughly check that all our circuits and projects do not infringe patents That is why we have a general disclaimer regarding this very topic in every issue – see page 101.

Choice anxiety for non-hybrid cars

Why do people who purchase non-hybrid cars suffer from "choice anxiety"? You do not hear of people choosing black cars and then writing about why they did not buy a white car. E. Murdoch writes in the May 2014 issue about his experiences with the cars he has owned. He makes interesting comments but then, at various places in his writings, tells us about hybrid cars, promulgating information which is simply not true.

For example, he claims without justification that diesel-powered cars are more economical than hybrid electric-petrol cars, which is simply that energy technology is approaching anyway and cannot accept the performance limitations of current renewable technology.

It is not that renewable energy systems don't work; they don't work as well as current thermal power generation technology, as Germany found about a year ago when the wind faltered across Europe and decommissioned fossil fuel stations had to be rapidly reinstated. Perhaps we should try another approach, redesigned around the renewable energy limitations. Surely this is better than banging our heads against the realities of physics.

Kelvin Jones,
Kingston, Tas.

Wooden spoon for the energy debate?

Having been born into the heart of industrial England in 1946 with its terrible pollution sourced from fossil fuel I am a firm believer in phasing out this type of energy source as soon as practical. This is irrespective of any global warming considerations. The improvement in the environment of my birth place outside Manchester UK with the advent of North Sea gas never ceases to amaze me each time I pay a visit.

It was the atmospheric air deposits trapped in the annual ice layers in the Arctic regions that gave science the hard evidence of the exponential rise of CO_2 in the atmosphere since the early 1700s and it is still rising.

The climatic effects which are attributed to the Greenhouse Effect are of much publicised scientific debate, along with an equal amount of disinformation being put out by vested interests. The initial push for renewable energy was to avert a projected tip into a new ice age. The practicality of doing this has proved to be both politically and technically impossible, without serious consequences to the population as a whole if carried out in the short time frame that would have been necessary.

Most of the all-powerful monetary economic system seems to be locked into the "infinite expansion" mentality, regardless of the physical limits

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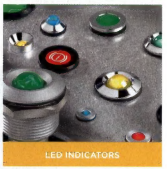

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A WORLD OF
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Mailbag: continued

Postage for warranty repairs can be expensive

New products can be faulty, so watch the return postage costs for "Under Warranty" repairs when making a purchase. I recently purchased a new 10.1-inch tablet on eBay. I did notice that the seller was in Hong Kong but as he had sold numerous other units and the item was brand new, I didn't foresee any problems.

The first surprise was when I booted up the tablet and found a screen full of Chinese language characters. Fortunately, I recognised a drop-down menu and found the word "English". I clicked on it, and the page dissolved into English.

The next surprise appeared two weeks later when the "On/Off" switch developed a fault. The seller said the unit would be repaired under warranty. I took the parcel to Australia Post and found they would not accept it due to the batteries. I also found that the cheapest courier service to Hong Kong wanted some $87 (another 17% of the purchase price) to return the unit.

I then tried the Australian company workshops, to see if they would honour the 2-year warranty. They said "No", as they could not re-install the Chinese software. I then asked if I could pay them to repair the On/Off switch. Again, "No", for the same reason.

I then obtained quotes from local tablet repair companies, who quoted $120 but said they might not be able to obtain a new switch from Hong Kong and the courier costs would additional.

At the time of writing, my tablet is in Hong Kong and the switch has been replaced. I just hope the repair is successful as I certainly had not anticipated these extra costs when I made my initial $514 purchase.

Tony Farrell,
Kingscliff, NSW.

not true and for good technical reasons. Later on he says, out on the free way they don't really offer any better fuel economy than regular petrol cars; again, simply not true.

The most successful petrol electric hybrid cars use an Atkinson Cycle petrol engine, which has a very similar thermodynamic efficiency to a diesel engine. The reason why such an engine is not used in ordinary cars is that it cannot be made to idle satisfactorily.

One of the main strategies used in a hybrid car to gain good fuel efficiencies is to not deploy the internal combustion engine in that part of the load range where it has poor efficiency, to wit at light throttle settings and low speeds. Avoiding this part of the load range not only works well but also makes the use of the Atkinson Cycle engine a practical reality. (Atkinson designed an engine that used a mechanically complicated mechanism to produce asymmetric stroking. The modern engine described with that name uses valve timing to produce a similar thermodynamic effect but it deserves a better name as such an engine is nothing like Atkinson's design.)

My Toyota Camry hybrid not only returns excellent fuel consumption figures in stop-start driving in traffic but also at speed. This is not because it is a hybrid but because it has an Atkinson Cycle engine – and it is better than a diesel because the engine is smaller than a diesel engine would need to be to power the vehicle alone. Note that an internal combustion engine has its best thermodynamic efficiency generally at about 80% of maximum RPM and at or very near full throttle. It would be at full throttle if it were not for the fact that most car engines run with a slightly rich mixture at wide open throttle settings to enhance the power output, a strategy that reduces the thermodynamic efficiency.

If you could change the displacement of an internal combustion engine on the run then you would choose the smallest displacement that would provide just enough power. However, without a hybrid set up you need an

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Mailbag: continued

Global warming is nonsense

After reading the large number of letters in your May 2014 edition, I am absolutely amazed at the number of people who are still being sucked into believing this global warming nonsense. With regard to climate change, I am quite prepared to accept this because, as we all know, the climate is changing slightly all the time.

I can quite clearly remember swimming in the sea in early to mid-November in the late 1940s. Nowadays one is still wearing warm attire in November sometimes, as the real summer doesn't seem to appear until well after Christmas now. Another problem I have is with all this ballyhoo about carbon dioxide in our atmosphere; do any of those who support this fantasy threat ever stop to consider just how much carbon dioxide is released into the atmosphere every year by all the various volcanoes around the world? The eruption in Iceland not so long ago released more carbon dioxide into the atmosphere than mankind has done since the dawn of time, yet our planet hasn't warmed at all in the past five or six years or so.

If all those climate change/global warming fanatics were to apply their energy into something practical, I'm sure we'd all benefit.

John Macdonald,
Geelong, Vic.

engine big enough for overtaking and accelerating but such a choice at all other times is a fuel liability. This is why a small Atkinson engine does better than a stand-alone diesel engine which would need to be bigger.

Toyota plans to have a hybrid option on every one of their vehicles by 2020.

If people continue to promulgate false information about hybrid cars they are not helping others make good choices. From the list of bells and whistles E. Murdoch describes I think I can guess the make of car he is discussing and that make of car only offers a poor rendition of a hybrid; another manufacturer that thinks like many, including E. Murdoch, in hoping that the idea will go away.

Dr Kenneth E. Moxham,
Urrbrae, SA.

Off-grid products are often unreliable

I found the Publisher's Letter in the April 2014 issue most interesting and although I agree with much of its content, I might add some home truths regarding the nature of hidden costs of green technology. I am not against such technology but I don't believe its what it's cracked up to be. My technical background covers some 40 years in electronics, ranging from manufacturing to service and repairs of scientific apparatus, and also training workplace staff and the public on the use of equipment.

Presently, I work for a well known company in Brisbane which sells power inverters and chargers, MPPT solar

regulators and other small accessories to customers for Off-Grid systems such as marine, caravan, camping and recreational vehicles, to name a few. I have also worked with some On-Grid equipment as well as some back-up storage systems.

My role in the company is to service the equipment, when it comes in for warranty assessment and/or repair. I also handle, on a daily basis, incoming technical calls from the general public and electricians, as well as our own sales staff. I also deal with the "manufacturing side" of such equipment in that I report back to the companies that make these products overseas, on any unusual faults as well as technical issues customers are experiencing in the field with these newfangled devices.

Most, if not nearly all, of the devices on the market are not able to be repaired at component level. Specialist parts are not obtainable and circuit diagrams are not passed onto their service agents like myself. Fuses are soldered into the PCB and components are crammed so tightly that one needs specialist tools to carry out any repair work. If you're keen enough to carry out a repair, it's often only a training exercise for one's self. Some ICs have the type numbers ground off, so there is no way you can identify the part without a circuit diagram.

Software is highly guarded and often changed, so it's incompatible with older models that may still work perfectly. Most of the control electronics is surface mounted and covered in glues, lacquers and bonding cements – so you cannot extract it without serious damage. Likewise with hair-thin copper PCB tracks.

As you may have already concluded, this means 98% of items are made to be thrown away and if repaired, whole PCBs have to be replaced. Yes, it is back to being a board jockey – if you can get the PCB!

If the warranty expires or the fault is outside warranty, the item is then scrapped and deemed B.E.R – "Beyond Economical Repair" (unless you're like me who still tries to resurrect such for my own use). Most of the items are designed in Europe and are not suitable for Australian conditions; 40°C ambient temperature being considered hot in Europe, despite the Bureau of Meteorology raising their temperature scale to 55°C recently. This makes the failure rate much higher than would be considered acceptable here. Some items I work on have a failure rate as high as 10%.

One well known battery charger I service, touted to be "the world's smartest charger", was measured by me with an infrared temperature gun in an air-conditioned workshop (about 27°C). It had a running temperature of around 85°C on some major components. Spit would sizzle on the iron-cored input choke. No internal fan was fitted as it was classed for an IP65 rating.

Another Chinese inverter-charger I work on has a design running temperature of 150°C for the output transformer. As a result, you would burn your hand on the core of the transformer at moderate load of, say, 1kW. You can even smell the varnish burning on the windings when under full load. Yet it's considered safe! The wire and insulation paper is rated for at least 150°C. This temperature rating makes for smaller size and less weight in the design.

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Mailbag: continued

Disagreement about ripple current

On page 94 of the April 2014 issue, you answered a question from M. F. who asked about the required ripple current rating of a power supply filter capacitor for a Luxman audio amplifier. I think your 'rule of thumb' that ripple current would be at least equal to the total current drain from the supply is misleading and falls well short of the mark.

I can't easily replicate the Luxman's supply but I have simulated a full-wave rectifier and capacitor filter circuit more than once and the results indicate that the ripple current in a filter capacitor is closer to 2.5 times the DC current drain.

I asked an experienced colleague what he expected the ripple current would be and his reply was two to three times the DC current. There's also this short quote from the National Semiconductor Corporation's Voltage Regulator Handbook (1982), Section 8: Power Supply Design: "RMS ripple current in a capacitor input filter is 2 to 3 times the load current."

However, there is another point that you have overlooked. The power supply current of an audio amplifier is certainly not a smooth or continuous DC current. When the output swings positive the amplifier draws current off the positive rail, and when it swings negative it draws current off the negative rail, such that for a sinusoidal output the power supply currents look like a half-wave rectified version of the sinusoidal output current.

This contributes quite significant ripple current (4.3A RMS) which flows through the filter capacitors, in addition to that due solely to charging the capacitors during each half cycle of the 50Hz mains. The current drawn off each supply (+ and -) from an amplifier delivering 75W per channel into 8Ω loads is 4.3A RMS and the average (ie, the DC value) is 2.9A. The total capacitor current (ie, the ripple current in each filter capacitor) is slightly greater than 7A RMS.

I suggest that a ripple current rating of 7.5A is just adequate for the described application, if M. F. is planning to run his amplifier at full power with 8-ohm loads, both channels driven with sinewave input, for significant periods of time. For music the peak to average ratio of signal power is reasonably high and hifi amplifiers are rarely expected to deliver their full power for any significant length of time. If M. F. is planning to use it only to play music and without causing significant hearing loss, 7.5A ripple current rating should be adequate.

Phil Denniss,
Darlington, NSW.

Added to this, many power semiconductors have poor design selection for their operating point, risking secondary breakdown issues. Thermal heatsinking is often inadequate and they are squeezed in between tightly packed parts. Most electrolytics are rated at 85°C, these being cheaper than 105°C types.

Confine all this in a tightly spaced box to make it small and attractive to the customer, with some items not including a "noisy" fan, and it's no wonder they don't last long. But in reality that is what many manufactures and distributors want – a high failure rate – so they can sell more items to customers.

Another major issue is that once you are "off the grid", you are on your own!

What I am finding is that most "grey nomads" have no idea what the difference is between different battery types, how to add parallel and series voltages, currents and capacities; how to set and operate their charging equipment correctly, or work out when their inverter is overloaded. They and many others treat an off-grid set-up the same as running straight from an on-grid power point. They just plug items in as if they were at home, with no thought about what the end result will be.

Loading up, say, a typical 5kVA inverter with numerous items, while having no understanding about start-

up surge currents and overload ratings, let alone inductive loading or battery chemistry, is a recipe for disaster. They usually destroy their batteries within 2-3 years. They then learn on internet forums or by word of mouth about how good lithium-ion batteries are. They rush out and buy a set, then just plug them in with no thought about battery management systems, charge rates or the upgrading of battery chargers. In some cases this has resulted in fire and destruction of their vans, boats and electrics, with maybe a few injuries and deaths involved.

When the whole lot goes bang and maybe even up in smoke, they then expect instant service (as they are desperate and have no other power available; not even a spare charger on hand) and call out the nearest local electrician or auto-electrician who has no understanding of DC principles or battery charging, let alone electronics and software programming. This shows a distinct lack of expertise in the community and as we all know, many electronic technicians have now left the industry because of their inability to obtain electrical licensing and the amount of throw-away technology that is constantly changing.

Another problem is that customers buy equipment totally unsuited for their application and then try and make do or modify the system outside its design capacity. When the gear blows up, they fall back on their consumer rights to get a refund, stating that the "equipment does not meet their needs". Sales staff unfortunately have no, or at best, little technical training and create half of the problem. The end result is that the industry gets a bad name, the company gets a bad name and technicians and sales staff leave as they are fed up with the stupidity and abuse from customers on a daily basis.

Tight financial margins also come

Better DAC for Tiny Tim

Further to the letter from R. P. in the "Ask SILICON CHIP" section of the April 2014 issue, I have one follow-up observation.

R. P. has had the same experience I had. The Samsung Series 8 TV that I have does not have an analog audio output and it does not allow down-mixing of the audio off TV channels broadcasting AC3 DD to feed to the optical output port.

The Jaycar DAC (Cat. AC-1631) that was recommended for use in the Tiny Tim Stereo Amplifier (SILICON CHIP, October & November 2013, January 2014) can't handle 5.1 channel AC3 DD. However, Jaycar have a new DAC (Cat. AC-1658) which solves the problem completely. I have purchased it and it down-mixes the optical output from my TV into 2-channel stereo regardless of which off-air channel is tuned.

This new DAC is about $30 more expensive but at least it works. How such an upmarket TV as a Samsung Series 8 could be sold without analog audio outputs, or the ability to down-mix multi-channel audio, defies belief.

Jim McLennan,
Belrose West, NSW.

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Mailbag: continued

into play, making items flimsy, poor in design and only rated for mediocre applications. One disgruntled boatie who screamed about me knocking back the warranty on his battery charger, claimed, rightly so, that it was IP67-rated, as it said so on the label. Yet it had a fan vent built in by the manufacturer and the upset owner believed you could hose it with water because it had "MARINE" written on the front of the charger (when you hose out the boat and maybe the batteries after fishing). "MARINE" in Europe does not mean the same thing as we believe it does in Australia.

Much of this is bought about about due to the ignorance of young engineers in these companies who have never worked in the real industry and sit on a computer all day running CAD and SPICE programs, yet have no idea of secondary breakdown region, isolation transformers, proper grounding techniques, surge current ratings and heatsink design, to name a few. They have a piece of paper from a university but no true design experience. Many don't even carry out electronics as a hobby at home and only encounter such in the workplace. Such is the nature of today's education system.

In the end, based on my own first-hand experience with ignorant end-users and profit-making manufacturers, I can't see this technology going much further than it already has, as much as I would like to believe differently.

Mobile reception in Black Rock

I respond to Stan Swan's letter in the Mailbag pages of the April 2014 issue, in which he responds to correspondent PM of Black Rock, Victoria. I live just down the road and in the last 10 years have complained endlessly and without resolution to the fact that I cannot maintain a mobile phone call when driving through Black Rock despite changes from CDMA to the current system.

I would also take exception to Black Rock being described as an outer suburb. Maybe 30 years ago, but not now. I live 15 minutes down the road and at Mordialloc we are no longer in the outer darkness.

The point? I see no reason why a telecommunications provider cannot provide a reliable service in a middle ring suburb of a major metropolitan city. I should, perhaps, point out that said provider has, at their own expense, provided me with a rooftop antenna and a coupling device simply to receive and send reliable mobile calls. And this is in a flat landscape!

Get it together guys. It shouldn't be this hard.

Angus Witherby,
Mordialloc, Vic.

I've already heard of a small few who have had so many dramas they have gone back onto the grid after a lot of expense and frustration.

In reality, as electricity costs go up, can you imagine a single mum with three kids managing a rental house on solar panels, inverters and batteries? Making a practical off-grid power system for renters would be a great idea but not so easy to manage. Most can't even pay their electric bill, let alone manage technical apparatus as described above.

Allow another 10-15 years by which time most of the grey nomads will have run out of money and want to sell their worn-out RV vehicles and campers (many now live in them as they have no other home). We will then have a major issue on our hands with homeless elderly people and those without electric power. Rising on-grid costs will push the lower end of the public off the grid altogether; it's already started. It will be back to candles and wood stoves and an increase in house fires.

Many going into retirement don't have the up-front funds to convert to off-grid power or stay on the grid as cost rise, as their superannuation funds are not big enough to cover such. Already the writing is on the wall – the lights will soon go out!

Kimbal Summers, Wishart, Qld.

Comment: there is no doubt that rising energy costs are causing a general lowering in the quality of life for older people and those on low incomes. This topic was covered in the Publisher's Letter in the September 2011 issue. The emphasis on reducing carbon emissions and on so-called clean renewable energy sources will have severe ramifications for older people in the future.

Food-free Fridays?

Following on from the Publisher's Letter in the April 2014 issue, once again, the high priests of the UN/IPCC

have forecast world starvation unless we mend our wicked ways. According to them, unless we curb our use of oil, gas, coal and meat, the carbon dioxide levels in the atmosphere will soar, the globe will heat up and food production will plummet.

This is just a rerun of their previous failed forecasts based on academic theories and computer models. They should have asked practical nurserymen, farmers and meteorologists.

Nurserymen would tell them that if you pump carbon dioxide into a greenhouse the plants grow faster, bigger, more drought-tolerant and more heat-tolerant. Therefore more carbon dioxide in the atmosphere will produce more food.

Farmers would tell them that plants grow faster in the warmth of spring and summer and slower in winter. Any warming by carbon dioxide would tend to warm the higher latitudes so the snow line will shift, thus creating more arable land. It would also tend to produce warmer nights, thus reducing frost damage to crops and opening more land to frost-sensitive crops.

Meteorologists would tell them that if global temperatures increase, evaporation from the vast oceans must also increase. What goes up with more evaporation, must come down as more rain or snow. While some areas may become drier, a warmer world is on average a wetter world, producing more food.

There is also no evidence that extra carbon dioxide and warmth will make weather more erratic – in fact the reverse should occur as the global temperature gradient which drives winds and storms will be reduced with more warming at the poles.

Finally, there is no evidence that their climate scares will occur "much earlier than expected". With global temperatures flat for 17 years, how can warming occur faster than in their previous failed forecasts?

There is no rational basis for claims that increased carbon dioxide in the atmosphere will add to world starvation; history and science tell us that it would produce a productive green and bountiful world. It is global cooling we have to fear.

On the other hand, there is no doubt that foolish climate policies will produce less food. Policies on ethanol, biomass, carbon-credit forestry and the Kyoto bans on regrowth control either directly consume food or reduce the land available for food production. Encouraging and protecting trees at the expense of grasslands is threatening the production of low-cost food from marginal grazing lands and water restrictions are driving irrigators out of business. To top it off, their taxes and regulatory wars on carbon energy will push marginal farmers and fishermen out of production. The world may indeed see hungry years but carbon dioxide will not be the cause.

Already greenies advocate "Meat-free Mondays". Their anti-food anti-carbon policies will soon result in "Food-free Fridays".

Viv Forbes,
Rosewood, Qld.

E-cigarettes now banned in Western Australia

With regard to the Publisher's Letter on the topic of e-cigarettes in the February 2014 issue and subsequent critical letters in the Mailbag pages of the March 2014 issue, readers may be interested to learn that e-cigarettes have been banned from sale in Western Australia, following a Supreme Court ruling in that state.

See **www.smh.com.au/nsw/eciga-rettes-case-goes-up-in-smoke-follow-ing-landmark-ruling-in-wa-court-20140419-36xih.html**

Richard Kidd,
Orange, NSW. SC

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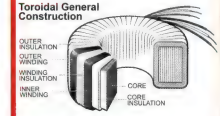

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A 2014 update on Australian ELECTRIC SUPERBIKES

Now *REALLY* moving!

With three years of development behind them and a successful launch on mainstream racing circuits last year, battery-powered electric superbikes are attracting even more attention – on and off the racetrack!

by Andy Marsh and Ross Tester

When SILICON CHIP visited the Sydney Motorsport Park at Eastern Creek last year, we came away mightily impressed with the electric superbikes not just on display but competitively racing (see "The Very Fast Sounds of Silence, SILICON CHIP, December 2013).

The technology behind what amounts to the very early days of this sport was simply staggering: we were amazed at just how far they'd come in such a relatively short period.

We put this down to the dedication and enthusiasm of the pioneers involved in the sport, just as much as the spectacular advances in technology which allowed so much electric power to be stored on what amounts to a pretty small frame – and then turn that power into performance.

As our December report showed, there were just three brands racing at Eastern Creek in 2013: Ripperton, Varley and Catavolt.

A new season

The biggest difference between the 2013 and 2014 seasons will be the number of competitors – potentially there will be seven electric superbikes

taking the starting grid at each of the four rounds.

Ripperton, Varley and Catavolt will all be back but there looks like being brand new offerings from a new Sydney-based team and also from Solar Power Australia, along with a re-entry to the field from Voltron.

The 2014 season of Australian Electric Superbike racing kicks off on 27-29 June at Queensland Raceway (Willowbank, near Ipswich), followed by round 2, 1-3 August at Winton Raceway, Victoria. Round 3 is on 12-14 September at Wakefield Park Raceway (near Goulburn, NSW) and culminating at the final round back at Sydney Motorsport Park, 21-23 November.

If you can get along to any of the tracks mentioned above, it's well worth it just to see the state-of-the-art in electric superbikes.

They're faster and more durable than last year's models as the eight months or so has seen an enormous amount of development in both batteries and motors, resulting in faster bikes, able to circulate for even longer.

If you're at all interested in the field, it's probably worth a look at that December 2013 article to see what was then the current state-of-play in electric bikes.

As we mentioned, the three main players were Danny Ripperton, the 2013 electric bike champion (Ripperton was not only the mover and shaker behind Ripperton ebike development, he was also the main rider); Varley, with their modified CBR600RR machine with Jason Morris aboard and someone we didn't see at Eastern Creek, Catavolt.

New bikes, new motors, new batteries

2013 has been a year of intense research, development and proving. It hasn't been without its problems, as you might expect – all teams suffered at least minor difficulties and one team experienced season-ending failures.

But all this has been "grist for the mill", so to speak, with the knowledge gained put to very good use as the teams face the new season of racing.

Ripperton

Ripperton electric, with their successful R1 ebike, will be undergoing something of a generational change in 2014, with the highly successful Danny Ripperton stepping off the bike and concentrating on the engineering side.

Ripperton currently holds the record at both the Queensland Raceway (the "paper clip" at Ipswich) and the Wakefield Park track in NSW.

The 90kW, liquid-cooled Ripperton Quad-Stack motor has been ultra-reliable and coupled with 7kW of hot-swap lithium batteries proved to be the most reliable of all machines – despite its lower performance (on paper) over, say, the Varley Electric bike.

Ripperton acknowledges that he's too heavy to allow his bike to be any more competitive. He believes they were the first race team to have the mechanic riding the bike but for 2014 they have finally levelled the playing field by getting a professional rider.

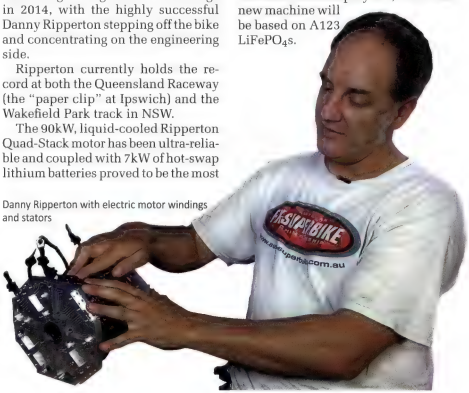
"With at least 40kg removed from the rider/bike package", he said, "the equivalent of 16 house bricks, the Ripperton machine promises to be a tough contender in 2014."

Varley

Varley electric motorcycles have the benefit of being part of a major player with 125 years experience in automotive, marine, aerospace . . . and elecric vehicles.

Based in Newcastle, NSW, Varley have products and expertise ranging from high power Ultramotive motors to Tritium power electronics and chargers – and they are determined to stay at the forefront of development of electric superbikes.

Their familiar modified CBR600RR will be joined by a new Ducati-based bike. Both are built around the 80kW Ultramotive Carbon electric motor and Tritium WS200 controller package. These run on a 448V DC supply but use different chemistries: the older bike uses lithium polymer, while the new machine will be based on A123 $LiFePO_4$s.



Danny Ripperton with electric motor windings and stators

Australian ELECTRIC SUPERBIKES

Television Series

You can now watch all of the electric racing on TVS. Series one of Australian Electric Superbikes will be broadcast on TVS on Saturday 31 May at 3:30pm and Sunday 1 June at 11:00am

Episode One
- The ultimate electric racer
- Lithium engineers
- The race is on
- Battery technology

Episode Two
- Lithium power
- Riders' view
- The second round
- Assault on the salt

As seen on tvs

Episode Three
- Pioneers
- Structural integrity
- Third time lucky
- Electric motors

Episode Four
- An old master
- And the winner is...
- Looking on
- Back from the future

www.facebook.com/australianelectricsuperbikes

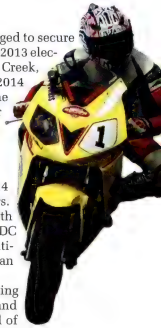
evmotorcycle.org

Danny, Jason and Victor

Ripperton R1 Electric Superbike

Jaron Ware from Batrium Technologies

Electric racers on the grid



Rider Jason Morris, who managed to secure two wins in the final round of the 2013 electric superbike series at Eastern Creek, will be back with Varley for the 2014 series. His 1:48.254 record for the 4.5km track is certainly under threat this year but Varley are hoping to keep it in the family!

Voltron

Voltron will be back in 2014 after a hiatius of a couple of years. Their bike is different again, with the Voltron EVO running with a DC bus of 620V DC. For the uninitiated, that's a higher voltage than Melbourne trams run on!

It all comes down to matching the capabilities of the motor and inverter. The motor's base speed of 4000 RPM is achieved with a DC bus of 600V. The last 1000 rpm must be achieved by engaging "field weakening". By defeating some of the motor back EMF, the rotor is capable of spinning faster, albeit at the expense of torque.

It is only by supplying at least 400V RMS to the motor, that it can reach the rated peaks greater than 150kW. This calls for an inverter capable of supplying some serious grunt and the Rinehart Motion Systems PM150DZ inverter is up to the task.

The VoltronEVO Electric Superbike uses a modular, multi-chemistry battery monitoring system (BMS) from Western Australia's EV-Power. Its four BMS modules can monitor 12 cells each.

It has inbuilt safeguards which will warn the rider if something goes wrong in the power department and rather than (dangerously) shutting off power completely, will go into a 'limp home' mode, enabling the rider to nurse the bike back to the pits.

One difficulty of running a 600V battery is that, hot off the charger, the pack can exceed 700V – contrary to eFXC rules. So they can be sailing pretty close to the wind, hoping that when measured, the scrutineer will record the battery voltage starting with a "6".

Another (minor!) difficulty of such a large battery pack is that at 85kg, it can't be lifted out by hand. A hoist is needed.

But further development by Voltron in both batteries and motors is aimed at both a smaller, lighter battery running a lower-voltage motor.

Catavolt

Catavolt are back too. The company which holds a land-speed record and a notable appearance at the Daytona International Raceway is determined to once again become a force in Australian Electric Superbike racing.

They suffered several technical mishaps in 2013 but the new R6 Catavolt ebike for 2014 is rather different to what we have seen in the past. For a start, their new Catavolt has swapped the enerTrack hub motor for an onboard power plant – this return to a more familiar drivetrain will provide a significant power increase.

The impressive 100kW motor is coupled with a 12kWh lithium-ion battery pack.

Anatomy of an electric superbike

Electric Superbikes may look similar to their internal combustion counterparts but the technology is taking motorcycle racing to the next level.

MOTORCYCLE FRAME AND CHASSIS

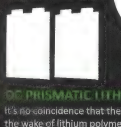
Modified internal combustion engine hardware is quickly being replaced with custom electric motorcycle frames. Bespoke chassis are designed using 3D development software and rapid prototyping. This process allows the engineers to package the electric drivetrain and components into a frame designed specifically for the task. Many of the successful designs are now forming the basis for mass production electric motorcycles.

HIGH VOLTAGE RELAY

For safety all Electric Superbikes must provide a high voltage cutoff relay. This device provides a method of disarming the high voltage supply. A large red button is positioned in a prominent position on the bike, which can be activated in case of emergency by either the rider or circuit marshalls/rescue crew.

AC CONTROLLER

Acts in the same way as a conventional throttle to vary the power delivered to the motor but also converts DC from the battery to the 3-phase AC required by the motor. A typical controller will handle 600A amps at 200V. Many of these electric superbikes have multiple controllers.



DC PRISMATIC LITHIUM CELLS

It's no coincidence that these Electric Superbikes have emerged in the wake of lithium polymer cell development. When combined in a battery pack, these prismatic lithium cells produce enough current to propel an Electric Superbike to over 200km/h. A typical racing pack is configured to 7kWh. It's a compromise between keeping the bikes light enough to be competitive while providing enough power for the electric motor. Building the pack so that it can be removed easily from the bike provides a distinct advantage for both charging and troubleshooting.

AC BRUSHLESS MOTOR

Ultra efficient electric motors generate massive amounts of torque from a small package. These integrated powerhouses can be used in double or even quad stack configuration. Super powerful permanent magnets are required to offset the electromagnetic force that is produced by the windings. Liquid cooling allows for higher continuous currents to be used by the electric superbikes.

This gives the R6 more than 900nm of torque – to put this into perspective, that's more than four times the torque of the popular Suzuki Hayabusa and in fact, is more than a Mclaren F1 supercar!

No rider has yet been named for the Catavolt but there's a queue of hopefuls stretching all the way down the main straight!

Two new teams

2014 is set to be an exciting year for electric superbike racing in Australia. Steady increases in performance levels have been experienced to the point where ebikes were consistently competing at over 200km/h.

But with new electronic and electric hardware coming on line, racing speeds approaching – and even exceeding – the 250km/h barrier are expected this year.

The existing teams believe they have sorted out most, if not all, of the technical issues which they've variously suffered in previous seasons (only time will tell if they're right!) but, more importantly, the new season will see another two teams competing in the electric superbike series, bringing the total number of bikes on the starting grid to seven.

Australian Solar Power are likely to enter a production Brammo machine, while an as-yet unnamed Sydney team plans to race a Yamaha 100kW R6 bike.

It's a great time to watch, and be a part of, Electric Superbike racing. It's still in its infancy in terms of the overall bike racing scene but already, we've seen the technology developing and maturing much faster than anyone could have believed would occur when it started three years ago. SC

Micsig MS510S Multi-function Oscilloscope

This portable unit has two fully isolated 100MHz scope inputs, a built-in isolated multimeter, 14.5cm (5.7") colour touch-screen, up to 190k waveform updates per second, 240k points memory and a battery life of up to 7 hours. It's supplied with a pair of isolated probes for measuring up to 600V (Cat II).

As portable scopes go, this new product from Emona has a lot of good features and comes at quite a reasonable price.

One of the reasons we asked to review this unit is that we recognise how useful it is to have a scope with two fully isolated channels; this makes it much easier to make measurements at two different points in a circuit which may not necessarily have the same ground reference.

However, you do have to be a bit careful using an isolated scope because this means that you can potentially (no pun intended!) have a high voltage not only between the input signal and ground but between those grounds and from each ground to earth.

So the probes and inputs need to be well-insulated to prevent accidental shocks.

This unit does not disappoint as it is supplied with two insulated probes that shroud the BNC connector shields, earth clips and test probes (to the extent possible). These are 500MHz, 10:1 types rated for 300V CAT III and 600V CAT II.

First impressions of the overall user interface are good. The screen has good contrast and colour and is easy to read indoors; it has an outdoor colour scheme which definitely helps for reading in sunlight. However the lack of an anti-reflective coating on the display means it would work a lot better with a hood or under shade.

The unit boots up fast – in just a couple of seconds – and responds to button presses pretty quickly. So it doesn't feel sluggish to use.

While the touch-screen can be used to perform many functions such as moving along the timebase, moving traces up and down, zooming into portions of the waveform and selecting measurements to display, virtually all functions can also be performed using the front panel buttons and side jog wheel (see photo at left).

The operation of this unit is quite different to most benchtop scopes but users will quickly figure out the controls and get used to them. Like most digital scopes, it has soft buttons (F1-F4) which drive the on-screen menus.

As you can also see from the photo, the control layout below these is pretty simple and the function of most buttons is self-evident.

Review by Nicholas Vinen

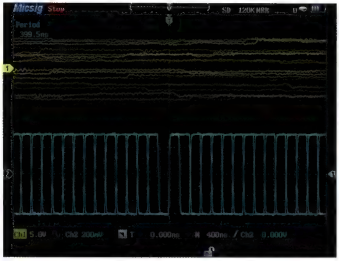


Fig.1: this screen grab operating in scope mode demonstrates the display persistence. One measurement has been enabled (period for channel 2) and this can be seen at the top of the screen. The lock icon at the bottom indicates that the touchscreen can be temporarily 'locked out' with a button press so accidental touches won't have any effect.

Fig.2: the unit operating as a multimeter, with the buttons to select various modes at the bottom of the screen. These can be selected using the touchscreen or side jog wheel. One soft button enables relative measurements while the other resets the statistics, displayed at the top of the screen. Time stamps for the min/max readings are a nice touch.

The scope is 165mm wide, 255mm tall, 62mm deep (not including side carry strap) and weighs 1.7kg. It has a tilting stand at the back to prop it up on a flat surface.

Supplied accessories include the two probes, a set of multimeter leads, mains charger, user manual and PC software on CD and warranty card.

Scope functions

Each channel has a selectable sensitivity of 5mV-50V/division so with the supplied 10:1 probes, that gives a range of 50mV-500V per division. The sampling rate is 1GS/s with one channel active and 500MS/s with two. As stated earlier, storage is 240Kpoints total so with both channels active it can store 120K samples. Channel bandwidth can be restricted to 20MHz if required and each channel can be AC or DC coupled.

This scope uses a 9-bit ADC which is slightly better than bargain basement scopes (including desktop models) which typically use an 8-bit ADC. As such, when the bandwidth is set to 20MHz, the traces are quite clean, however there is still a fair bit of noise evident with 100MHz bandwidth (this setting affects both channels simultaneously). You can of course enable averaging to reduce noise with repetitive signals; this is also enabled for both channels at once.

By default, the scope has trace persistence, which can be handy in some circumstances as it allows you to see the 'spread' of the signal, eg, get an idea of jitter in a digital signal or amplitude stability in an analog signal. But sometimes you want to turn it off to get a 'cleaner' looking trace – unfortunately, we can't figure out how to do that with this unit. The minimum persistence setting is 100ms. This isn't a huge problem but it does seem to be an oversight in the software.

You can display up to four measurements in scope mode, selected from a large list and these appear at the top of the screen, overlapping the graticule. They're updated a couple of times a second. The unit also has basic X/Y cursors that can be enabled and moved around in the usual way.

Typical trigger options are available, including Edge, Pulse, Logic (ie, high/high, high/low, etc), Video (including high definition) and Serial Bus. The hold-off time is adjustable as is the trigger coupling (AC/DC).

Serial bus decoding

While this is not a mixed signal scope, it does have an option to decode various serial buses and trigger on the contents of the packets. This includes serial, LIN, CAN, SPI and I^2C although given the fact that there are only two channels, it's more suitable for I^2C than say SPI.

The version we tested (MS-510S) has the serial bus decoding option; the MS-510IT is the equivalent model without it. The difference in cost is $888 + GST. That's quite expensive for a software option but if you need it, you need it.

Multimeter functions

The built-in multimeter is easy to use because of the large touch-screen. It's easy to switch modes by pressing on their icons and the numeric display is large. One aspect we particularly like is that it auto-ranges almost instantly, which overcomes one of the biggest arguments again auto-ranging meters (which, let's face it, are pretty much standard now).

However, there is one major drawback apart from the modest 4-digit resolution and that is that you need an external accessory to do current measurements – either a shunt or a hall-effect sensor (clamp meter).

These are available as accessories; however Emona do not currently list them or have a price. So that probably means you need a multimeter on hand, in addition to the MS510S.

But that's not to say the multimeter functions are useless – far from it. It offers DC and AC voltage in ranges such as 500mV, 5V, 50V, etc with a maximum of 1000V DC and 750V AC (20kHz bandwidth). The multimeter inputs are fully isolated from the scope inputs. It also does statistics (minimum/average/maximum) and has a bar graph in addition to the numerical read-out – see Fig.2.

Other modes include resistance (0-50MΩ), continuity (50Ω threshold), diode test (up to 3.5V), capacitance

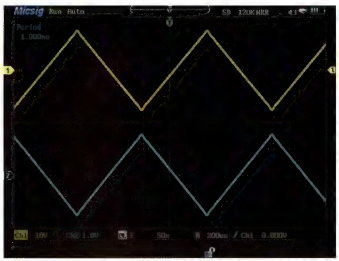


Fig.3: the 9-bit ADC means that the trace display is quite clean; much of the 'fuzz' visible here (such that there is) is due to the DAC producing the waveform, rather than the scope. The lack of signal linearity where the slope changes are quite clearly visible. It's possible to zoom in on a section of the waveform by dragging a box using the touchscreen.

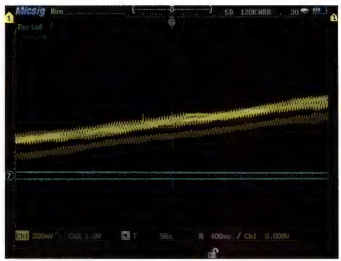


Fig.4: zooming in further, the bandwidth is sufficient to capture the DAC switching noise of the instrument producing the test waveform. The persistence allows two complete sweeps of trace data to be seen simultaneously; the persistence time can be adjusted to show more but with noisy signals, this can cause the display to become indistinct.

(100pF-50µF), temperature and humidity (again, requiring an external sensor accessory) and pressure (ditto).

One nice feature of the scope is that the multimeter inputs can also double as calibration outputs for the probes. Small adaptors are supplied to make the connections.

Data logging

The unit also has a "Recorder" mode where it can log readings from either the meter or scope input(s).

When logging from the meter, you can choose from DC volts, AC volts or DC+AC volts. You can also log DC amps, AC amps, temperature, humidity and pressure but all these extra modes require the appropriate accessory.

The readings are displayed in an automatically-scaled horizontally scrolling chart format and the data can then be saved to a USB flash drive (in a ".MMR" file format) or in a screen grab of the chart.

It can be set to either stop storing data when full, or set to a circular buffer mode where it overwrites the earliest data with later data once storage space is exhausted.

For data logging from the scope input(s), it can either log a low-frequency view of the two input channels or alternatively, it can log one or two of the scope measurements.

In the latter case, you need to first enable the measurements you require on the appropriate channels, then switch to Recorder mode and select the measurement(s) to log.

The logging frequency is 10 seconds to 20 minutes per data point in multimeter/scope measurement recording mode and 10 milliseconds to two minutes per data point in scope trace recording mode.

You can play back the recorded data on the unit or offload it to a PC for further analysis and plotting.

Connectivity & battery life

There are two USB sockets on the side of the device, one for a USB flash drive and one for a cable to connect to a computer. As described above, you can log data to the flash drive but you can also save screen grabs, settings and waveform data. Screen grabs can also be captured in multimeter mode.

When connected to a computer via a USB cable, custom Windows software is required to interface with the scope (supplied on the CD). This allows the unit to be operated directly from the computer and data (eg, waveforms) can be transferred to the PC.

The battery is a Lithium-ion type and is user swappable. There are two types, standard (4-5h) and extended life (6-7h).

We don't know which was supplied with our test unit but we ran it for a couple of hours and the battery meter still indicated it was more than half charged.

Charge times are similar to discharge times, ie, the standard battery takes about five hours to reach full charge.

Conclusion

As portable scopes go, this one is a pretty attractive proposition. Even for bench-top use, the dual isolated channels and ability to easily move it around are quite useful features. While we would like to see a couple of software tweaks and an anti-glare coating on the screen, it's a very flexible instrument with good overall performance and a responsive user interface.

While the MS-510S is not light, it can be operated hand-held and with the protective rubber surround, appears to be robust enough for field use.

The MS-510S is available from Emona for $2790 + GST. The MS-510IT, without the serial bus decoding option, is $1902 + GST. 200MHz models of both are available for an additional $191 + GST.

For applications where performance is not so critical, the MS-310IT is a cheaper option at $1446 + GST. The main difference is the waveform update rate – it's 190Ksamples/second for the MS-510 and less than 50Ksamples/second for the MS-310. Emona also carry the MS-200T series which are cheaper again but do not feature isolated inputs.

For more details, visit the Emona website at www.emona.com.au or e-mail testinst@emona.com.au

Alternatively, contact Emona head office on (02) 9519 3933. (Interstate office numbers are on their website). SC

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You can be justifiably proud that you crafted them
your friends won't believe you built them!

They're big, they're beautiful and they're mighty p

Everything about this superb loudspeaker system is impressive: size, physical presence, power handling, efficiency, extremely wide frequency response and low distortion. Is there a disadvantage? Well, they are somewhat big! On the other hand, if you already have large tower speakers, these won't take up much more space and will sound far superior. They look better too!

Introducing:

The Majestic

illiant . . .

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world!

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erful!

By Allan Linton-Smith

Let's face it; up till now it has been possible to build your own state-of-the-art amplifier, DAB+ tuner or DAC but Silicon Chip has never produced what we could claim as a "world-beating" loudspeaker system.

Now we believe we have such a design.

It can easily handle the power output of amplifiers rated up to 300 watts per channel but at the same time, it is very efficient. How efficient? 97dB/watt @1m.

To put that in perspective, that is between two and three times more efficient than typical hifi loudspeakers which are rated at around 87-90db/watt @1m.

What does that mean in practice? There are two answers. First, you don't need a large power amplifier to drive them to very high sound levels.

Say you wanted to produce sound levels of 110dB in your lounge room. That is very loud – about rock concert loud – but you would only need a 20-watt amplifier. Our 20-watt Class-A amplifer would be ideal.

Even a 5-watt stereo amplifier will drive a pair of Majestic loudspeakers to more than 105dB in the average lounge room.

Second, at the other end of the scale, with a 300-watt/channel stereo amplifier, you could drive a pair of Majestic loudspeakers to truly deafening sound levels in a large auditorium! In fact, at distance of 1 metre from the front of the Majestic loudspeaker, you would be blasted at 122dBA when fed with 300 watts. That's way above the pain threshold and well into hearing damage territory.

OK, you get the picture. It can handle lots of power and it is very efficient.

But the same comment applies to a lot of big public address speakers. However, most of those are just loud; they are definitely not hifi and they typically do not have a wide frequency response. More particularly, they do not have a bass response extending to below 20Hz.

In fact, in all our years of listening to high fidelity loudspeakers, we have never come across one that would produce fair-dinkum 20Hz. At the same time, that big 15-inch cone hardly moves at all even when producing high sound levels. That is the advantage of an effective cone area which is more than four times that of an 8-inch driver. A bigger cone means less cone travel and therefore less distortion.

Surprise!

If you are impressed so far, you will now be surprised. The woofer is Australian-made, an Etone 1525. This has a 2.5 inch voice coil and has a free-air cone resonance of 27Hz. It is teamed with a Celestion CDX1-1730 com-

WARNING!

Silicon Chip takes no responsibility for broken windows, cracked masonry or porcelain, unstable foundations, unstable relationships, neighbourhood rioting, replacement of vital organs or loss of bridges, skyscrapers or other infrastructure resulting from these speakers being driven at high level – especially after midnight. Nor do we take responsibility for air turbulence which may result in unstable or out-of-control airliners, helicopters, hang-gliders or UFOs which may result from use (or misuse) of this speaker system. Silicon Chip firmly believes in responsible sound levels and tasteful music. AC/DC excepted (or is that accepted?).

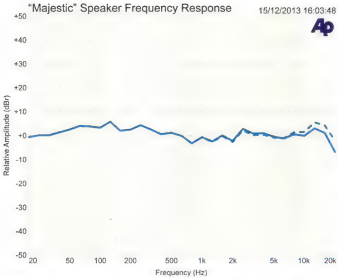


Fig.1: frequency response for the Majestic Speaker – while the overall flatness is very good, what's astounding is the fact that there's barely any discernible roll-off in bass response at 20Hz! The dotted line shows the effect of the treble boost network.

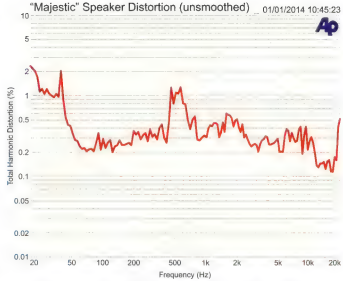


Fig.2: distortion remains low at most audible frequencies. The spike between 350Hz and 800Hz is likely due to interactions between the drivers around the crossover point, while the spikes below 50Hz are due to the increase in cone excursion and resonances.

pression tweeter driver mated with an Etone H2017 horn. These are fed through a simple first order crossover network which gives attenuation at the rate of 6dB/octave above and below the crossover frequency for the woofer and tweeter, respectively. We will describe the crossover network in detail later in this issue.

Beautiful finish

And while you might love the sound quality from the Majestic loudspeaker, that could count for nothing if your partner hates its appearance. After all, DIY loudspeakers and hifi speakers in general seldom win awards for attractive appearance.

But we think we also have a winner on this score too, because the cabinets look absolutely superb!

Believe it or not, they are based on panels from the German-made but readily available "Kaboodle" Flatpax Kitchen Cabinet System.

Now before you start thinking "Oh no! Not kitchen cupboards!" you really have to see the finish of these panels to believe them. They are anything but "cheap and nasty". In fact, there is only one word to describe them: Majestic!

Construction of the speakers is basically the same as that of a free-standing kitchen cabinet: you first build the "carcase" and then add the glossy piano-finish panels. Because we're not adding a granite or stone benchtop, we use another panel to create the top of the case.

Using these panels means that you can build high quality cabinets for a fraction of what you'd expect.

Mind you, if you want to keep your partner happy, you had better let the decorator of the house choose from the large range of finishes available from the Kaboodle cabinet range. Why not try a black piano finish...or be daring and go for "seduction red" in full gloss, or a more conservative

The Magestic Speaker Specifications

Power Handling:	up to 300W RMS
Sensitivity:	97dB /1 watt @ 1m
Frequency Response:	20Hz – 20kHz, +6/-3dB *(see Fig.1)*
Distortion:	<2.4% 20-50Hz; (typically less than 0.5%)
Size (each cabinet):	486 (w) x 864 (h) x 580 (d) (mm)
Weight (each cabinet):	48kg
Woofer:	Etone 1525 15", 2.5kg magnet
Tweeter:	Celestion CDS1-1730 compression driver, Etone H2017 horn
Crossover:	2-way first order (6dB/octave slope)
Cost to build:	~$1300 per pair *(estimated at June 2014 prices).*

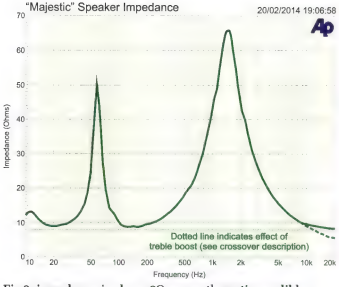


Fig.3: impedance is above 8Ω across the entire audible frequency range, making the amplifier's job driving the speaker easier and thus keeping distortion low. The two main peaks are at 58Hz (cabinet resonance) and 1.5kHz, due to the effect of the crossover network.

"Myrtle gloss"? If you want it all to match with some modern colour schemes you might even like to use "Mocca Latte" and let the speakers blend into the background.

Kaboodle Flatpax are sold by Bunnings Hardware and are available throughout Australia and New Zealand. Many Bunnings outlets have samples of their finishes on display so you get to look and touch them before you decide.

We originally chose ultra-gloss white for our prototype, mainly because it was immediately available but we had to concede that it wasn't real pretty – in fact, about as attractive as a bar fridge.

But we all liked the sound, so much so, that one of our staff members decided that he must have a pair finished in "Red Oak" (the ones in our main photos with the lovely Tianna showing just how big they are!).

These particular panels usually need to be ordered and might take a few weeks for delivery.

So what will it all cost?

Our pair of prototypes finished in Red Oak with woofers, tweeters and crossovers, came in at under $1300 (for the pair).

That's an absolute steal compared to anything with even remotely similar performance currently on the market.

For example, consider the JBL S4700 3-way loudspeakers. These are taller than the Majestics and are rated at 300 watts and 94dB/W @1m. They use a 15-inch woofer with dual 3-inch voice coils and a cast aluminium frame. This is mated with a 2-inch compression driver and bi-radial horn, topped off with a 0.75-inch ultra-high frequency driver and bi-radial horn.

Rated frequency response is 38Hz to 40kHz at the -6dB points. Cost for a pair is around $20,000. (No mention of 20Hz though!)

Frequency response

Probably the most important function of any loudspeaker is its ability to accurately reproduce the full spectrum of sound in the audible range, especially at high sound pressure levels.

When we say big, we mean it: the woofer is an Australian-made Etone 1525. This 15-inch powerhouse has a free-air cone resonance of 27Hz. The tweeter (inset at top) is actually a hybrid: a Celestion CDS1-1730 compression driver, teamed with an Etone H2017 horn. Individually, these components are impressive. Combined, they're formidable!

We have probably all experienced PA systems which are painful to the ear, not always because they are too loud but because they have poor frequency response and some frequencies completely dominate everything especially in the painful mid range region.

To gain a pleasant sound we have aimed at developing an exceptionally good frequency response combined with

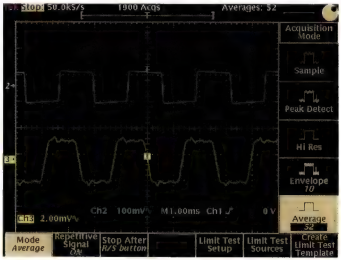


Fig.4: the top trace is a square wave signal being fed into the amplifier while the bottom trace shows the output of a microphone positioned in front of the speaker. The first-order crossover and good time alignment give excellent waveform reproduction.

The Magestic
Speaker Parts List

Timber requirements (per enclosure)

Kaboodle Carcase Kit (all 16mm HMR panels)
Bunnings Part No W-51604
Back panel 720 x 418mm
Bottom panel 544 x 418mm
Side panels 720 x 560mm (2 in kit)
Top support panel 418 x 80mm
Shelf (becomes angled 'diffuser' panel) 416 x 540mm

Kaboodle Dress Panels (18mm high gloss finish)
Side Panel (2 required) 864 x 580 x 18 **(Bunnings part**
Door panels – 717 x 447mm - 2 required. **nos depend on**
(1) becomes front baffle – used full size **colour chosen)**
(2) becomes top panel and bottom rear panel
[top panel is cut to 580 x 447;
bottom rear panel (450 x 126mm) is cut from excess]

Extra support panels (not supplied in kits)
Back top support 418 x 150 x 16mm (particle board)
Baffle support 418 x 80 x 16mm (particle board)
Horn panel 615 x 126 x 3mm (3-ply)
Cleats: cut from 2.4m x 25 x 25mm DAR maple or similar

Other components required (per enclosure)

1 Etone 1525 15" Woofer (**www.etonesound.com**)
1 Celestion CDX1-1730 Compression Driver (**www.elfa.com.au**)
1 Etone H2017 Horn (**www.etonesound.com**)
2 rolls bonded acetate fibre (acoustic wadding) 700 x 1000mm
1 Crossover *(see article commencing on page 32)*
1 2m length of draft exclusion strip (10mm wide)
1 pair heavy-duty panel mount polarised speaker terminals
~ 2m heavy-duty figure-8 polarised speaker wire
1 tube (& dispenser) neutral-cure silicone sealant
14 50mm woodscrews
27 28mm woodscrews
20 20mm panhead woodscrews (for woofer/tweeter mounting)
8 m3 x 20mm machine screws with nuts and washers
4 100mm L-shaped brackets

high efficiency and low distortion.

Impedance

We have paid a lot of attention to the impedance versus frequency characteristics of the Majestic speaker because this can be a major factor in the performance of the driving amplifier.

Some amplifiers will misbehave if the impedance drops too low – they will either be over-loaded or their distortion will become quite bad. But even where an amplifier can comfortably drive a loudspeaker with the expected dips in impedance, it will also give lower distortion into a higher impedance load.

You can see plenty of evidence of this with the distortion versus power and distortion versus frequency characteristics for driving 4 or 8-ohm loads. The 8-ohm figures for SILICON

One speaker box almost finished – with the top panel still to be cut and glued in place (no screws used here!) and the speakers, crossover, terminals and hyperbolic horn panel to be fitted. Note that we have left the protective plastic covering in place during construction . . . just in case.

CHIP designs are always better and for many commercial amplifiers they can be markedly better.

Ergo, our aim was to have a loudspeaker system impedance which does not drop below 8 ohms at any frequency. In fact, as shown on Fig.3, the Majestic speaker is well above 8 ohms for the whole audio spectrum.

So it will be compatible with just about any amplifier – and given its high efficiency, even very low power amps (eg, ~1W!) will drive it, right through to big amplifiers with the rated 300W maximum.

The crossover network is quite simple and is covered in a separate article in this issue. In brief, it is a two-way crossover network which provides for minimum phase change across the full audio spectrum.

Frequency response

The graph of Fig.1 says it all: the Majestic's frequency is within +6, -3dB across the entire audio spectrum from 20Hz to 20kHz.

This is one of the best graphs we've ever seen in a high-power loudspeaker – again, even many big-name speakers with prices in the stratosphere aren't this good!

Of particular note is the low frequency response – it goes all the way down to 20Hz – but off the graph it keeps going down to 12Hz. That is just amazing! This is bass that you really feel.

Distortion

Speakers are still the weakest link in the audio chain.

Having gone to enormous effort to build or buy an amplifier with almost immeasurable distortion, there's not a great deal of point in feeding it into a speaker with high distortion.

We measured one popular brand of speaker and found more than 20% THD at the low-frequency end!

As shown in Fig.2, the Majestic speakers have distortion figures of less than 1% from 50Hz to 20kHz and for much of the audible range, they're less than 0.3%. Even at 20Hz, distortion doesn't rise above 2.4%. By the way, this performance graph was taken at a power level of 1W.

Of course, part of the reason for the low distortion is the use of that 15-inch woofer – its cone hardly deflects at all unless you are driving it to bedlam levels.

Drive the Majestics hard and all you'll experience is arguably the best bass you've ever heard!

Incidentally, our distortion measurements were made using some very high performance microphones but even the very best will introduce their own distortion. We measured our microphones at 0.38% so the actual distortion could be lower than in the graph!

Cabinet vibration

It is vital that a speaker enclosure be as rigid as possible, to prevent the panels vibrating and resonating at different frequencies and power levels. Any panel vibration is bad as it will add colouration to the sound in the best (least worst?) case and simply unpleasant buzzing and rattles in the worst case.

One of the advantages of using the "Kaboodle" panel system is the rigidity of the cabinets. The thermoformed side panels are almost 19mm thick and the HMR chipboard inner panels are 16mm thick. Glued and screwed together, this near-35mm thickness of the two side walls provides excellent damping and also means that no internal bracing is required. Top and front of the cabinets only have the thermoformed panels but these also have support brackets and cleats, further assisting in their rigidity.

We used two rolled-up 700 x 1000mm sheets of bonded acetate fibre wadding inside each speaker to minimise internal standing waves and damp resonances.

On completion, as a test we placed piezo sensors on the cabinet panels and found no major problems across the audible range.

If you do find any vibrations in your Majestic speakers, they will probably be caused by insufficient attention being paid to assembly – particularly loose screws or lack of silicone sealant between joints.

How it works

The speaker box is essentially a bass reflex design with a tuned port but there are a number of important refinements. It is referred to as a bass reflex because the sound waves from the back of the woofer pass through the port and are radiated from the front to reinforce the sound from the front of the cone. Most of this reinforcement only takes place at low frequencies and it leads to a considerable extension of the very low bass response.

The tuning of a bass reflex enclosure results in two low frequency impedance peaks which straddle the free-air resonance of the woofer, which in this case is at 27Hz. As you can see from the impedance curve shown in Fig.3, these two peaks are at 58Hz and 12Hz.

Now there are two ports in the enclosure, the main one

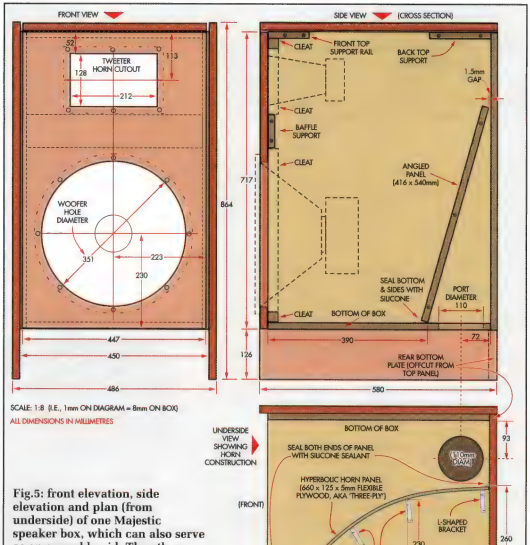
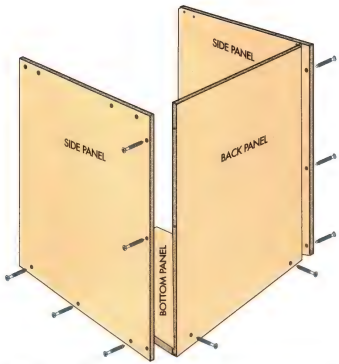


Fig.5: front elevation, side elevation and plan (from underside) of one Majestic speaker box, which can also serve as an assembly aid. The other prototype boxes were made mirror image but in hindsight, we don't think it matters: both left and right boxes can be identical.



STEP 1: after cutting any panels required as per the parts list and diagram overleaf, fasten back panel to bottom panel using silicone sealant and 50mm woodscrews (these holes are pre-drilled in kit). Attach the side panels to bottom panel and back panel using silicone sealant and 50mm woodscrews. Allow sealant to dry.

STEP 2: Drill holes in top of side panels and attach front and back top support rails. Plae 50mm woodscrews in the holes and temporarily assemble (ie, tighten woodscrews) to ensure everything is in the right place. If OK, lloosen the screws and again run a 5mm bead of silicone sealant in the join. Retighten and allow to dry overnight.

being the 110mm hole in the base and this is tuned to about 20Hz. However, while the main port itself is tuned to 20Hz, that is modified by a second port formed by the 416 x 540 x 16mm angled panel inside the enclosure which is mounted to produce a gap of 1.5mm and an overall port area of 63cm^2. This lowers the enclosure tuning and results in a low frequency peak at 12Hz.

The angled panel also reduces effect of sounds from the back of the woofer being reflected back through the cone and also damps (smooths) the low frequency response.

The low frequency energy emerges from the downward firing port and is then radiated by a half-hyperbolic horn with a mouth area of 559cm^2. However, this horn has no real effect at very low frequencies and its main function is to damp any "chuffing" which may result at high signal levels from the port.

Just incidentally, the horn also encloses are area underneath the box to accommodate the crossover network PCB.

Construction

The "Kaboodle" system is very easy to assemble and you really only need to follow the instructions provided for a really professional look. Bunnings also have available a DVD to give you some guidance.

Most of the construction follows the same steps as building a kitchen cabinet, the main difference between basic 450mm-wide kitchen cabinets and our Majestic speakers is just the drivers!

OK, so we've made a few modifications – these are all explained in the step-by-step diagrams.

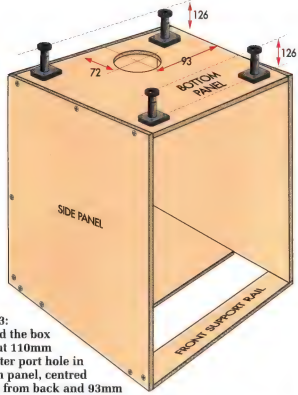
There are a few important things to keep in mind:

(a) Leave the protective plastic coating on the gloss Kaboodle covers until the speakers are complete. They'll minimise damage from any "oopses".

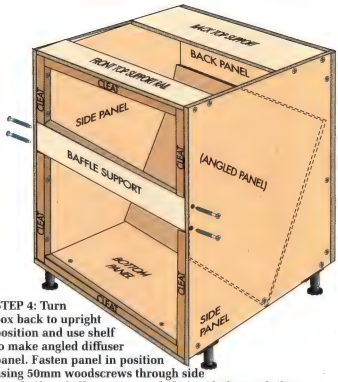
(b) All joins must include a bead of silicone sealant to ensure they are airtight. We used bathroom caulking compound which has good adhesive properties. Too much sealant is better than not enough – but be sure to clean up any excess as you go.

(c) Openings for the woofers and tweeters need to be cut in the 'door' panels. These are best cut from the non-glossy side with a jigsaw fitted with a fine-tooth blade.

It looks just like a kitchen cupboard carcase (!), albeit with a couple of extra braces. The angled panel (made from the cupboard shelf) is visible in this shot, taken before the dress panels were fixed in place.



STEP 3: Up-end the box and cut 110mm diameter port hole in bottom panel, centred 72mm from back and 93mm from side. Temporarily attach the four adjustable feet to the bottom of the box with four x 28mm woodscrews on each foot, first drilling appropriate holes. Using a straight edge, adjust all four feet so they are 126mm above bottom panel.



STEP 4: Turn box back to upright position and use shelf to make angled diffuser panel. Fasten panel in position using 50mm woodscrews through side panels (first drill appropriate holes) and plenty of silicone sealant. (Remember the 1.5mm gap between the diffuser panel and back panel). Add baffle support using 50mm woodscrews. Cut and place six cleats around front edge of box (cleats cut from 25 x 25mm DAR maple), secured in position with silicone sealant and 32mm woodscrews.

The same comments apply when you cut the top of the other 'door' off to become the top of the cabinet.

(d) You will need some extra 16mm MDF or particle board cut to the dimensions given in theparts list to make up the three support panels.

(e) The four adjustable feet supplied with the Kaboodle kit are used only to ensure the side panels are mounted in the right place, after which they are removed and discarded.

(f) The angled panel (the Kaboodle shelf) is secured by placing it inside and use some strips of masking tape to secure it at the bottom. Check the measurements. Set the top gap 1.5mm out using some pieces of scrap pc board held in place with masking tape and then use a liberal amount of silicone sealant on the sides because there is a gap to fill. Allow plenty of time to dry.

(g) The hyperbolic horn is made from a piece of 660 x 125 x 3mm plywood bent into the appropriate shape. 100mm "L" brackets hold this in position. Mounting this in the position indicated in Fig.5 should result in

Wiring the speakers: this is done immediately before STEP 8 above - ie, just before the top is glued on. Note the extensive use of silicone sealant around the seams to ensure they are totally air-tight. The holes where the wiring passes through should be similarly treated. This photo was taken of the first (white)prototype – in the final version cleats were added to support the panels.

There's a 1.5mm space between the top panel and side panels. Here's a nifty way to ensure that space is constant: use some offcuts of PCB or similar and place in the gap while the sealant dries. Be careful not to get any sealant on the panels.

STEP 5: The glossy dress panels are secured using a 'criss-cross' pattern of silicone sealant and 28mm long wood-screws screwed in from the inside of the box (drill only 5mm pilot holes into the dress panel to ensure they don't emerge from or marr outer surfaces). Use five screws on each panel in addition to silicone sealant. The bottom of the dress panels should line up with the bottom of the adjustable feet (ie, 126mm below the bottom of the box).

STEP 6: Turn box upside down again and remove the temporary adjustable feet (from now on the speaker will sit on the dress panels). Cut the "door" panel to 580mm and use the offcut as the support panel at the bottom rear of the box. Cut the holes for the woofer and tweeter in positions shown earlier and secure the panel in place with silicone sealant, then fit the horn panel (660 x 125mm strip of 3-ply) and secure in place with right-angle brackets. Seal the ends of the horn panel to the side and back panels with silicone sealant.

the hyperbolic shape.

(h) Cut the 110mm hole in the base before assembly

(i) The glossy side panels are criss-crossed with silicone sealant, then clamped and drilled before the screws are fitted.

(j) When cutting holes for the woofer and tweeter, mark out the woofer on the underside of the glossy door panel with a large compass or better still use the cutout provided in the Etone box as a template. Be very careful and check your measurements twice! Then gently drill a 9mm starting hole well inside the line and cut the hole with a jigsaw keeping the glossy side DOWN. Then mark the rectangle for the tweeter and drill and cut this with the jigsaw.

(k) Test the holes with by carefully lowering the speaker drivers. They should fit easily and not bind. Remove the speakers then add felt "weather seal" strips under the edges of both the woofer and tweeter to form an airtight seal when they are permanently fitted.

(l) The wiring to the speakers pass through suitable holes (only as big as necessary) in the bottom panel. These holes need to be made airtight with silicone sealant.

(m) Connnections to the Etone woofers need to be soldered but the Celestion tweeter takes spade connectors. If you use crimped connectors, ensure they are firmly crimped in place and when fastening to the speakers, that they cannot come loose.

(n) Soldering heavy duty wire requires more heat than a typical 20 or 30 watt hobby iron can deliver. A 50W iron or gas-powered iron is much better.

(o) The driver units are mounted using 10g x 18-25mm stainless steel woodscrews or screws with T-nuts.

(p) Two rolls of bonded acetate fibre are used in each box. Mount the rolls side-by-side to make it possible to access the speakers between them.

Breaking in and testing

Out of the box you will find that the bass drivers are very stiff and won't deliver their optimum performance until they have had a 'break in' period. Simply allow them to run under normal conditions with various types of music played at different levels. You should notice an improvement over time.

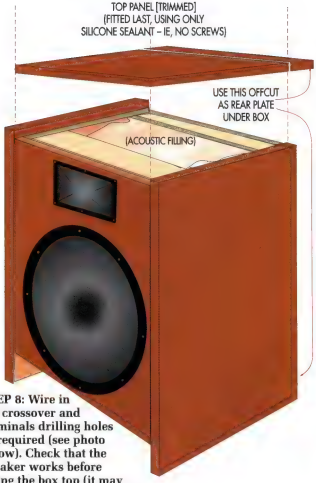
Even though they are rated up to 300W RMS this is the rating for normal music. Don't be tempted to run a continuous tone from a signal generator or test CD at high levels – you risk permanently damaging your speakers (and your ears!).

Even with the high power handling of this system it can

WHERE IS *The Magestic* CROSSOVER?

As the crossover is suitable for many other speakers, we decided to make it a separate article – you'll find it starts on page 32.

STEP 7: Attach front baffle board (another piece of glossy panel) from the inside, using 28mm woodscrews through the baffle support and edge cleats. Fill interior of box with two rolls of acoustic wadding side-by-side and mount your pre-wired speakers (woofer and tweeter) to the outside of the baffle using suitable woodscrews or screws and "T-nuts" which grip the timber on the inside (ie, place the nuts via the top of the box with the wadding pushed out of the way) .



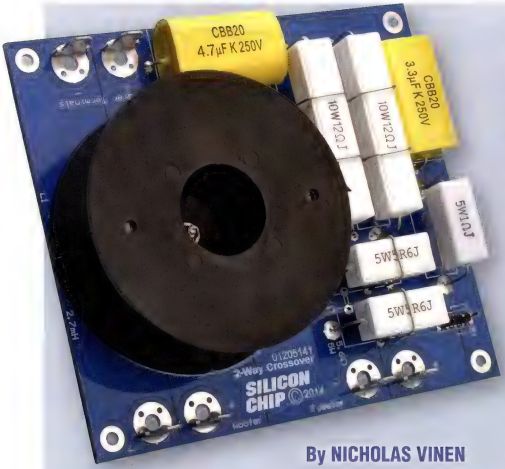
STEP 8: Wire in the crossover and terminals drilling holes as required (see photo below). Check that the speaker works before fitting the box top (it may not sound real good without the top fitted – just ensure it works!) The trimmed door panel, which forms the top of the box, is secured in place using only silicone sealant (no screws!). Ensure that sufficient silicone sealant is spread along entire length of support panels and cleats to form an airtight join and is weighed down until the sealant has dried.

be damaged by a relatively small amplifier which clips severely. The only 100% certain way to tell if the amplifier is clipping is to observe the signal on a scope – but if the speaker output sounds harsh and unnatural, the chances are the amplifier is clipping.

Finally, note that once the top panel is secured in place with silicone sealant, it is difficult – if not impossible – to remove without major damage. Make sure it works first! If you need access to the box internals, you'll need to remove the woofer and work via its mounting hole.

Because the top panel is secured only with silicone sealant, it's essential that the join is compressed so the sealant spreads over all and forms an airtight seal. Use a heavy weight to force the panel down – but protect the surface!

Fitting the crossover: actual position is unimportant but make sure all wiring is secured to the panel and/or cable clipped. The 3-ply "horn" panel looks much thicker here than it really is – we've attached some self-adhesive tape to prevent the speaker scratching our polished floor.



While this crossover network PCB was specifically developed for the Majestic 2-way loudspeaker system featured earlier in this issue, it can be used anywhere a 2-way loudspeaker crossover network is required. It has an optional treble peaking circuit which can be switched in and out to compensate for tweeter roll-off at high frequencies and also incorporates a high power attenuator for the tweeter.

By NICHOLAS VINEN

2-Way Crossover Network With High-Power Attenuator

THIS CROSSOVER works very well in the Majestic loudspeaker system, giving it a commendably flat frequency response with low distortion and excellent power handling. But it's also suitable for other 2-way speakers systems, such as tower or bookshelf units. The component values just need to be changed to suit the driver and cabinet properties.

As with the crossover network built into just about all hifi loudspeaker systems, this circuit is passive, ie, it has no 'active' electronic circuitry to provide the required attenuation of the drivers above and below their respective crossover frequencies. We published an active crossover network in the January 2003 issue and this could be configured as a 2-way or 3-way crossover. However, while active crossovers do have some advantages, they are a much more complicated approach because separate power amplifiers are required to drive the woofers, tweeters and midrange speaker (the latter being required for a 3-way system).

Passive crossovers

Why is a crossover network required? First, because woofers do not reproduce high frequencies and tweeters do not produce low frequencies. Second, because woofers may produce a distorted output of high frequencies and tweeters can be damaged by too much low-frequency signal. So, for a 2-way system, involving just a woofer and tweeter, we separate the audio signal from the amplifier into two frequency bands: low and high. For a 3-way system with woofer, midrange and tweeter, we separate the audio signal into three bands: low, midrange and high.

This ensures that each driver (ie, woofer, midrange and tweeter) is fed only with a frequency band it can effectively reproduce. The crossover network must also set the signal levels of the two (or three) frequency bands to achieve an overall flat frequency response. Typically, the woofer is less sensitive than the midrange and tweeter, so the signals to the latter drivers must be reduced so that the

output levels from all the drivers are well matched. Hence, our 2-way crossover incorporates an attenuator for the tweeter.

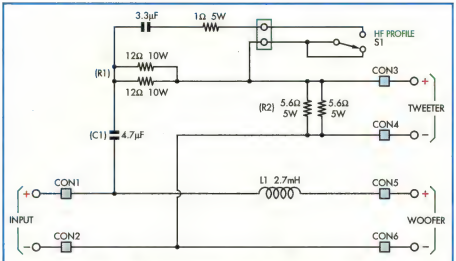
OK, our 2-way system has a low-pass filter to driver the woofer and a high-pass filter to drive the tweeter. Such filters can be first-order, second-order, third-order, etc. A first-order high-pass filter rolls off the signal above the corner frequency at 6dB/octave; quite a gentle slope. A second-order filter rolls off at 12dB/octave; a steeper slope. We are using the simplest filters, ie, first-order.

When the low-pass and high-pass filters which comprise the crossover have the same corner frequency, it theoretically gives flat amplitude and power responses (ie, no peaks or dips in the output), which no other type of crossover can achieve. Another unique property of first-order crossovers is their ability to retain the input waveform's shape once the tweeter and woofer outputs are combined, 'in the air'.

These ideal properties assume that the drivers have a perfectly flat frequency response, that they have perfect time alignment and that the listener's ear is on-axis equidistant from them. That's an unlikely set of circumstances but if you refer to the Majestic Speaker design you will see that despite this, the overall result using the first-order crossover is very good.

However, first-order crossovers provide a signal roll-off that is not very steep and this means that each driver receives substantial signal content beyond the crossover point, at reduced but still audible levels. So this type of crossover is best used with drivers with a significant overlap in frequency-handling capability. For example, if you have a woofer rated for 30Hz-1.5kHz and a tweeter which will handle 750Hz-20kHz then you have one octave of overlap (750Hz-1.5kHz) and so they should work quite well with a first-order crossover.

Actually, it isn't strictly necessary that they operate over a wide range of common frequencies; what really matters is that they do not misbehave when driven with a signal somewhat outside their design range. This means that tweeters must be robust enough to accept some low-frequency signal without damage and their resonant frequency should be high enough that it is outside this overlap zone. For woofers,



SC 2014 FIRST-ORDER LOUDSPEAKER CROSSOVER

Fig.1: the crossover circuit is quite simple, consisting primarily of inductor L1 to act as a low-pass filter for the woofer and a 4.7µF capacitor as the high-pass filter for the tweeter. Resistor pairs R1 and R2 attenuate the tweeter signal so that its output level is matched to the woofer. The remaining components form a switchable treble boost circuit.

this means that they should not generate excessive distortion when driven with low-level signals above their normal upper operating frequency.

Tweeter attenuator

Because the tweeter is usually more efficient than the woofer, we also use a resistive divider to attenuate its signal. This can be omitted if not required.

The horn-loaded tweeter used in the Majestic Speaker has an efficiency of around 109dB/W@1m while the woofer is 97dB/W@1m – and this is a very efficient woofer.

You might think that we could attenuate the signal using a single resistor, ie, put an 8Ω resistor in series with an 8-ohm driver to halve the voltage level and thus provide 6dB of attenuation. However, this also increases the source impedance "seen" by the driver by 8Ω (from the very low figure provided by the power amplifier) and performance will be significantly impacted due to poor damping.

By using a divider, we place a low resistance across the driver and thus keep its source impedance low. In fact the source impedance is the parallel value of the two legs of the resistive divider, typically around 2Ω. The driver is thus better damped, keeping distortion low. The resistive divider also provides more precise attenuation as it swamps the effect of the tweeter's inductance.

Power dissipation in this resistive divider is a significant issue. In the Majestic Speaker we are attenuating the signal to the tweeter by 12dB and that means 75% of the treble power delivered by the amplifier is turned into heat by the resistors. At a peak program power of 300W, that's a lot of power to be dissipated! But there are a couple of reasons why we can get away with much lower-rated resistors.

Even when driving the speaker at a peak of 300W, the average program level will typically be only a small fraction of this; maybe 10W or 20W, at most. Secondly, a good deal of that program power will be going to the woofer.

With a typical recording, the energy in each octave is about half that of the octave below. So even though we using resistors with a total power rating of 30W, for home (hifi) use, these should be more than sufficient. For PA use, it would be a good idea to mount higher-rated resistors on a heatsink and wire these up to the board instead, via the provided spade-lug mounting pads.

Circuit details

The circuit of the 2-way crossover network is shown in Fig.1. The sole component of the low-pass filter for the woofer is a series inductor, which for the Majestic Speaker and its 8-ohm driver is 2.7mH.

This is a standard air-cored choke, used because air is a perfectly linear core material. Its resistance is a little over 1Ω. The rising impedance of this inductor, coupled with the (more or

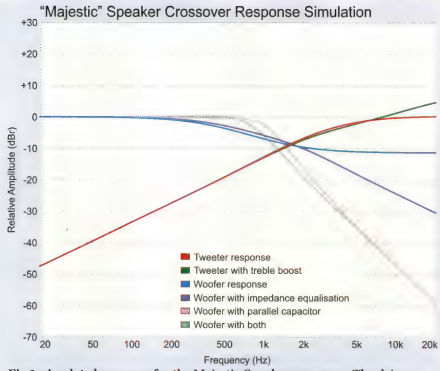


Fig.2: simulated response for the Majestic Speaker crossover. The drivers are simulated as 10.2Ω/1.8mH (tweeter) and 9.3Ω/1mH (woofer). The woofer response doesn't drop much below -10dB due to the voltage divider formed by its own inductance and the 2.7mH filter inductor. The tweeter plot has been raised by 12dB to allow for the difference in driver efficiency.

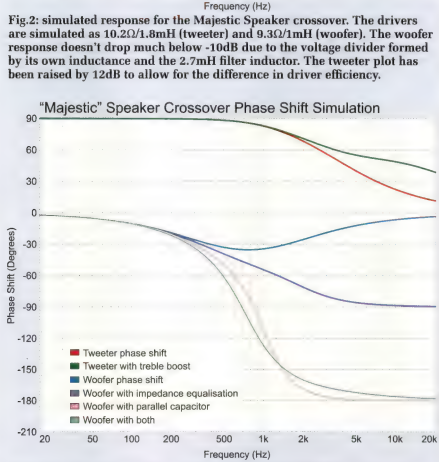


Fig.3: phase diagram for the same set-ups as in Fig.2. With the crossover as designed, the phase shift is around 90° across most of the frequency range. Circuits with faster roll-off have more phase shift.

less fixed) impedance of the driver, rolls off the signal as the frequency increases.

Actually, since the voice coil is also an inductor, at higher frequencies the driver's impedance also begins to rise, leading to a shelving effect, as seen in the simulated response of Fig.2. This could have been tamed using an impedance equalisation network (involving an extra capacitor and resistor) however with the Majestic Speaker the woofer's natural roll-off combines with the crossover to provide sufficient attenuation at higher frequencies.

Similarly, the high-pass filter for the tweeter is basically just a series capacitor, which is 4.7μF for the Majestic Speaker. As with the woofer, the tweeter is also an 8-ohm driver.

The corner frequency (-3dB) points can be calculated as follows. For the woofer it's $F = R \div 2\pi L$ which gives us 472Hz with a 2.7mH inductor and 8-ohm woofer. For the tweeter it's $F = 1 \div 2\pi RC$. For a 4.7μF capacitor and 8-ohm tweeter, that gives us a figure of about 4kHz.

As you can see from Fig.2, the roll-off points are quite far apart but remember that the drivers themselves have some roll-off which is not shown here (as this is an electrical simulation) and these values have been chosen imperically to give the flattest response (see Majestic Speaker article for details).

Given these formulae, you can adjust the components used in the crossover board as desired. We're assuming that if an attenuator is used for the tweeter, its impedance is the same as the tweeter's nominal impedance. The calculations below show how this is achieved.

Table 1 gives some example values that could be used. Normally, you would start with similar turnover frequencies for bass and treble but experimentation may show, as with the Majestic Speaker, that changing one or both slightly can give a flatter response when the driver and enclosure characteristics are taken into account.

Attenuator design

The following calculations allow you to select attenuator resistors based on the difference in driver efficiency from the manufacturer's data. However, note that due to cabinet design etc, you may need to tweak it from there. The upper resistor in the divider is R1 and the lower resistor (to ground) is R2.

The calculations are:

$$R1 = Z \times [10^{(A \div 20)} - 1] \div 10^{(A \div 20)}$$

$$R2 = Z \div [10^{(A \div 20)} - 1]$$

Where A is the required attenuation

Woofer Reactance & Filter Compensation

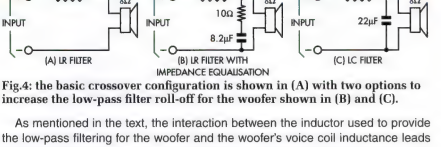


Fig.4: the basic crossover configuration is shown in (A) with two options to increase the low-pass filter roll-off for the woofer shown in (B) and (C).

As mentioned in the text, the interaction between the inductor used to provide the low-pass filtering for the woofer and the woofer's voice coil inductance leads to a shelving effect where the level applied to the woofer drops to about -12dB and then stays flat for high frequencies. We then rely on the woofer's insensitivity to high-frequency signals to continue the roll-off for us.

However, this isn't always desirable. Some bass drivers will reproduce higher frequencies but add significant distortion. In this case, there are some ways to defeat this effect and cause the response to continue to roll off.

One way is to add a so-called 'impedance equalisation' network consisting of a series resistor and capacitor across the woofer – see Fig.4(B). While the voice coil's impedance rises with increasing frequency, the impedance of this network drops with increasing frequency and thus the overall impedance remains relatively stable. This prevents the shelving effect from occurring and allows the roll-off to continue, as can be seen in Fig.2 (light mauve trace).

Another possibility is to change the LR filter [with the 'resistor' being the driver; Fig.4(A)] to a second-order LC filter, by placing a capacitor across the driver – see Fig.4(C). This requires a larger capacitor value but provides a much steeper 12dB/octave roll-off compared to the 6dB/octave of the first-order filter. It does, however, dramatically increase the phase shift of the signal reaching the woofer and thus the phase difference between the tweeter and woofer (see Fig.3).

This can cause 'lobing' and 'beaming' due to constructive and destructive interference between the audio coming from the tweeter and woofer, which adversely affects the speaker's directivity and frequency response. That is why why we have avoided doing this.

Finally, it's possible to combine these two approaches, with a capacitor across the woofer as well as an impedance equalisation network. This gives a similarly steep roll-off to the LC filter but with more attenuation around the corner frequency and with slightly less phase shifting of the signal (light green traces).

Overall, the configuration we have used has the most benign phase shift for the bass signals, with a maximum of about -45°, but it does rely on the bass driver being well-behaved at higher signal frequencies. If using this board with a different speaker design and different drivers, you may wish to experiment by adding an impedance equalisation network.

in dB and Z is the driver impedance. If we plug in the figures for the Majestic Speaker of 12dB attenuation and 8Ω tweeter impedance, we get R1 = 5.99Ω and R2 = 2.68Ω. To save time, you can use this online calculator: **www.sengpielaudio.com/calculator-Lpad.htm**

We're paralleling pairs of resistors for reasons of power handling, so this means we chose two 12Ω 10W resistors for R1 and two 5.6Ω 5W resistors for R2. The latter gives 2.8Ω, resulting in an inconsequential error of -0.2dB. These calculations give an overall nominal impedance that's almost identical to that of the driver itself, in this case 8Ω.

Treble peaking circuit

All that's left to describe is the treble boost step circuit. Its effect is shown in Fig.2. Essentially, it just reduces the attenuation of the resistive divider slightly, starting at about 7kHz and ultimately providing about 4dB of boost. This is designed to correct a roll-off in the response of the tweeter used in the Majestic Speaker above 10kHz.

We determined by experimentation that this capacitor value is close to optimal and that the resistor value is not critical but it works best when it's reasonably low, so we settled on 1Ω.

Because some recordings may have excessive sibilance, thereby making

Parts List

1 PCB, code 01205141, 107 x 120mm
1 2.7mH air-cored inductor (Jaycar LF1330)
1 M4 x 10mm machine screw and nut
1 300mm length 0.7mm diameter tinned copper wire
6 PCB-mount 6.3mm spade connectors, 5mm pitch (Altronics H2094) (CON1-CON6) OR
6 chassis-mount 6.3mm spade lugs plus M4 machine screws, shakeproof washers and nuts
1 3-pin header, 2.54mm pitch (CON7)*
1 jumper shunt*
1 SPST or SPDT toggle switch*
1 2-way cable terminated with female header plug*
4 No.4 x 12mm self-tapping wood screws
1 20 x 20 x 5mm section high-density foam rubber or synthetic rubber material

optional component for treble peaking network – see text

Capacitors

1 4.7μF polypropylene crossover capacitor (Jaycar RY6954)
1 3.3μF polypropylene crossover capacitor (Jaycar RY6953) (optional, for treble boost)

Resistors

2 12Ω 10W 5%
2 5.6Ω 5W 5%
1 1Ω* 5W 5%

Note: values listed are for the Majestic Speaker & may need changing for other designs – see Table 1.

Additional Parts For Connecting To Speaker

1 pair long binding posts, red & black (Altronics P2004/P2005)
8 yellow 6.3mm female crimp spade "quick" connectors (Jaycar PT4707, Altronics H1842)
1 2m length heavy duty figure-8 speaker cable (eg, Jaycar WB1732, Altronics W2130)

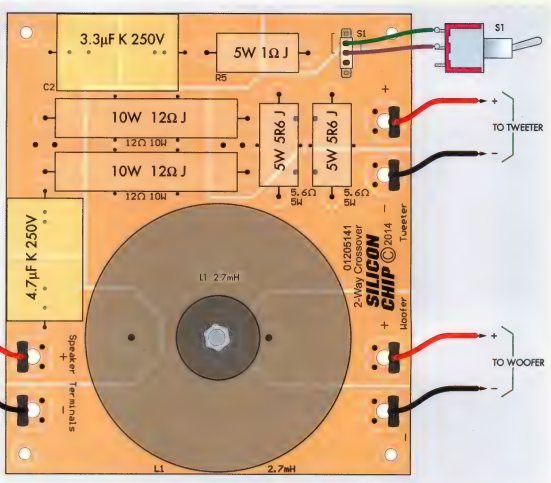


Fig.5: follow this PCB layout diagram to assemble the crossover. It includes provision to connect off-board attenuation resistors via spade terminals if required for very high continuous power applications (eg, PA). Note that extra pads are provided for wire supports for four of the wirewound resistors, to help take the stress off their lead solder joints (see text).

Table 1: Inductor/Capacitor Values & Associated Turnover Frequencies

8-Ohm Woofer		8-Ohm Tweeter	
Inductance (L1)	Turnover Freq.	Capacitance (C1)	Turnover Freq.
0.47mH	2.71kHz		
0.56mH	2.27kHz	1.5µF	13.3kHz
0.82mH	1.55kHz	2.2µF	9kHz
1.0mH	1.27kHz	3.3µF	6kHz
2.7mH	471Hz	4.7µF	4.2kHz
3.0mH	424Hz	5.6µF	3.6kHz
5.6mH	227Hz	6.8µF	3kHz
9.0mH	141Hz	8.2µF	2.4kHz
12.0mH	106Hz	10µF	2kHz
4-Ohm Woofer		**4-Ohm Tweeter**	
Inductance (L1)	Turnover Freq.	Capacitance (C1)	Turnover Freq.
0.47mH	1.35kHz		
0.56mH	1.14kHz		
0.82mH	776Hz		
1.0mH	637Hz	3.3µF	12kHz
2.7mH	235Hz	4.7µF	8.5kHz
3.0mH	424Hz	5.6µF	7.1kHz
5.6mH	114Hz	6.8µF	5.9kHz
9.0mH	70Hz	8.2µF	4.9kHz
12.0mH	53Hz	10µF	4kHz

Table1: this table shows the inductance (L1) and capacitance (C1) values to use for various turnover frequencies. L1 ensures that low-frequencies are fed to the woofer, while C1 ensures that high frequencies are fed to the tweeter.

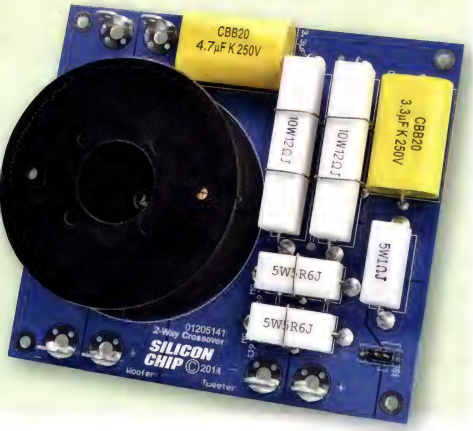
high-frequency treble boost undesirable, there is provision for this network to be switched in and out. You can of course link out the switch header if you want it to be permanently in, or leave the components off if this feature isn't necessary for the speaker you are building.

We feel that with the Majestic Speaker, its sound is improved with these extra components included.

Construction

Fig.5 shows the PCB layout. Start with the spade lugs; we used the PCB-mounting type however chassis-mounting spade lugs can also be pressed into service. For the PCB-mount type, there are various ways they can be fitted as there are four holes per position but we aligned them with the board edges and placed them as close to the edge as possible.

Solder them in place with a high-power iron. Start with the pins on the bottom side but it's also a good idea to ensure that there are solder fillets from the top side pad to the sides of the spade connectors too.



If using chassis-mounting spade lugs, use either the single-lug type or cut off one lug from a double-lug connector. Install each one by first feeding an M4 x 6mm machine screw up through the hole in the bottom of the board, then fit a shakeproof washer, then the connector, then another shakeproof washer and finally the nut. Tighten the nut with the lug projecting out from the edge of the PCB.

The capacitor(s) go in next. Bend the leads to fit the pads and push them down so they sit flat on the PCB before soldering them in place. Note that we have provided multiple pads in case you prefer to use radial types (eg, X2-style polypropylene capacitors). Polyester capacitors are not ideal as they are less linear but would probably work OK.

The capacitor next to L1 must be fitted. The other is optional depending on whether you want the treble boost feature. Solder the capacitor leads on both sides of the board, assuming you're using the specified axial capacitors.

We've provided pads so that the wirewound resistors can be supported by sections of stiff tinned copper wire, so that if they are exposed to shock or vibration, their primary solder joints are not the only means of support. You don't have to fit these support "trusses" but it's probably a good idea to do so (see photo above).

They are made as follows. First, bend the resistor leads so that they fit through the holes in the PCB, then cut a length of tinned copper wire at least 100mm long, straighten it and bend it through 90° about 20mm from one end.

Place this end of the wire parallel with the resistor leads, with the longer section resting across the bottom of the resistor body and with the shorter section aligned with the edge of the resistor, then wrap the longer section of wire tightly around the resistor body, going over the top and then across the bottom again. Finally, bend this end through 90° so that the remainder of the wire is parallel to the initial short section and lined up with the other side of the resistor body.

You will need two support wires for each 10W resistor and one each for two of the 5W resistors. These support wires are then fed through the appropriate holes on the PCB at the same time as the resistor leads.

These supported wirewound resistors should be spaced off the PCB by about 6mm. That's done by pushing each resistor down onto a 6mm-thick spacer. You then turn the PCB over and solder the leads, along with the support wires. The resistor leads should be soldered on both sides of the PCB (not necessary for the support wires).

The 1Ω resistor has no provision for support wires and can be pushed all the way down onto the PCB if desired, as it handles relatively little power.

The next step is to fit a pin header to connect S1, if you are using it. Once it's in, install inductor L1. First, scrape the enamel off its two leads; they are supplied pre-tinned, however the tinned sections are too far from the bobbin to allow it to be soldered to the PCB. You will have to scrape them back to the point where they exit from the bobbin, then tin those sections.

It's then just a matter of mounting the inductor in place and securing it using an M4 machine screw and nut before soldering and trimming the leads.

Mounting & connecting it

We mounted the crossover in the Majestic Speaker as follows. First, we marked out the four mounting hole positions in the bottom of the speaker (on the opposite side of the divider from the port) and drilled these to a depth of about 10mm with a 2mm bit. We then cut a 20 x 20 x 5mm piece of high-density foam into four sections and drilled 3mm holes through the middle of each section.

We then fed a self-tapping screw through each of the four PCB mounting holes and slipped the foam sections over the screws. The assembly was then lined up with the pilot holes and the screws tightened progressively until the four pieces of foam were well compressed. This provides a shock-absorbing mount for the board and also helps prevent the screws from vibrating loose.

It was then just a matter of crimping 6.3mm yellow female spade connectors onto the ends of the wires from the woofer and tweeter and plugging these into the appropriate connectors on the PCB. We also made some 150mm-long spade-lug to spade-lug cables using spare speaker wire off-cuts to connect the input terminals on the PCB to the binding posts mounted on the rear panel of the speaker.

If using the treble peaking switch, drill a hole through the rear panel and wire the switch up across one of the pairs of terminals marked on the PCB (ie, the middle pin and one of the upper pins). Alternatively, use a jumper shunt instead, shorting out the indicated pins to enable the treble peaking or placing it across the lower pins to disable peaking. SC

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2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103131	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSIC DAC MAIN PCB	APR 2013	01102131	**$30.00**
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	**$25.00**
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D +12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L'IL PULSER MKII TRAIN CONTROLLER	JUL 2013	09107131	$15.00
L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
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PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	**$4.00**
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	**$30.00**
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp (Sept'11))	OCT 2013	01309111	**$20.00**
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-5	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above (Nov 2012/May 2013))			
LED PARTY STROBE (also for Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
BASS EXTENDER Mk2	JAN 2014	01112131	$15.00
L'IL PULSER Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102124	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
PRECISION 10V REFERENCE	MAR 2014	04104141	$5.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
NEW THIS MONTH:			
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00

Touch-Screen Digital Audio Recorder Pt.1

By ANDREW LEVIDO

Want to record & play back with CD sound quality? With a compact hand-held unit with a colour touch-screen? Now you can. This device records to & plays back from a standard SD card and doubles as an SD card reader when connected to your PC via its USB interface. A single AA-size lithium-ion cell provides hours of record or playback time and is recharged via the USB port.

WHAT'S THE FIRST thing you will notice about this Digital Sound Recorder? It has no external controls! Just like smart phones and tablets, everything is done via the touch-screen. All its inputs and outputs are at the top end of the case – stereo line inputs with adjustable gain, a mono external microphone input jack and an in-built electret microphone, with two settings for gain (again, via the Touch-screen).

Audio output is via a stereo line output jack (3.5mm socket) and a headphone jack (3.5mm socket) with its volume adjustable via the touch-screen. Also at the end of the case is the SD card socket and a single LED that indicates when card read or writes are in progress. And there is a mini USB socket for communicating with a PC and charging the battery.

It records and plays standard WAV format audio files and is compatible with any PC or Mac. It supports 16-bit stereo PCM coded files at sample rates from 8-96ks/s.

The touch-screen display is a 72mm (diagonal) QVGA (quarter VGA or 320 x 240 pixels) TFT model. It has a white LED backlight and supports 262 thousand colours (although only 65 thousand are allowed for by the software).

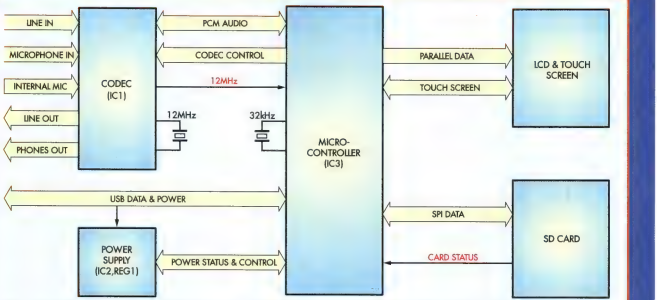


Fig.1: the block diagram of the Touch-Screen Recorder. A TLV320AIC23 CODEC (IC1) takes care of all the analog signal processing, plus analog-to-digital and digital-to-analog conversion of the audio streams. This interfaces to a PIC32 micro (IC3) via two serial data paths (PCM audio & CODEC control) and the micro in turn drives an LCD touch-screen display and an SD card. Microcontroller IC3 also provides USB support.

We have made the user interface intuitive, with on-screen buttons and text, and the display also shows the date, time and battery charge state.

To conserve the lithium cell, the backlight automatically dims after 30 seconds of touch-screen inactivity and it immediately brightens again when the screen is touched. The recorder goes to sleep after a further 30 seconds of touch-screen inactivity, provided it is not recording or playing and is not connected to a USB power source. Simply touching the screen wakes it up again.

When a PC is connected, the recorder can be put into SD card reader mode. The SD card will appear to the PC (or Mac) as an external disk drive, so files can be transferred back and forth. Mind you, to transfer a lot of files it will be quicker to remove the SD card from the recorder and insert it directly into your computer or a dedicated card reader.

So why would you bother to use this recorder rather than using your smartphone? The quick answer is great sound quality. This recorder gives you CD sound quality which your smartphone simply cannot!

How it works

For all of its fancy features, the Touch-Screen Recorder only uses a couple of chips. Basically, all it has is a CODEC (coder-decoder), a PIC32 microcontroller and the LCD touch-screen This is shown in the block diagram of Fig.1. The TLV320AIC23 CODEC takes care of all the analog signal processing, plus analog-to-digital and digital-to-analog conversion of the audio streams.

This interfaces to the PIC32 microcontroller over two serial data paths, one bidirectional path for the PCM audio data and one single-direction path for CODEC control. Two of the microcontroller's three Serial Peripheral Interface (SPI) modules are used for these interfaces. The CODEC requires a 12MHz crystal for timing and provides a buffered clock output, so we have used this to provide the main clock input for the microcontroller.

The microcontroller's third SPI module is for communication with the SD card. Two digital inputs monitor the state of the card presence and write protect switches in the SD card socket.

The LCD is driven via an 8-bit parallel interface with read, write and chip select lines. Although mechanically integrated with the display, the touch-screen is electrically separate and is essentially an analog device, so it is connected to pins on the micro that can double as analog inputs.

More details of how the touch-screen works are given later.

Main Features

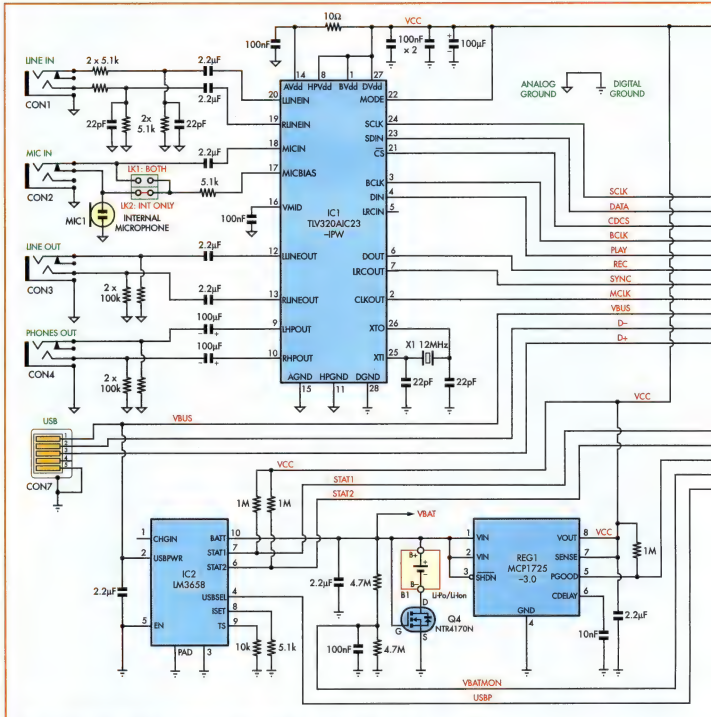
- CD sound quality
- Colour touch-screen with no external controls
- SD card memory
- Powered by a single AA-size lithium-ion cell; recharged via an on-board USB port

The USB socket connects directly to the microcontroller and the 5V USB bus power feeds a dedicated lithium-ion battery charger IC. The battery voltage can vary from 4.2V to 3.2V and is regulated to provide a 3V rail for all of the electronics (except for the display backlight that uses the unregulated battery supply).

The microcontroller monitors the battery voltage via an ADC input and this, together with status outputs from the battery charger and regulator, allows the micro to display battery status.

More detail

Let's now refer to the main circuit diagram for more details – see Fig.2. At the top lefthand corner, we can see that the stereo line input jack (CON1) is connected to the CODEC line input, pins 19 & 20, via voltage dividers



TOUCH-SCREEN DIGITAL AUDIO RECORDER

and 2.2µF blocking capacitors. These dividers ensure that the input impedance is approximately 10kΩ and attenuate the line level signal, which can be as high as 2V RMS, to a maximum of 1V RMS – the full scale input level for the CODEC.

The CODEC contains a digital gain/attenuation stage for the line input that can be set to any value between -34.5dB and +12dB in 1.5dB steps. The line inputs can be muted under control of the micro (IC3).

The mono microphone input (CON2) is connected to the CODEC via another 2.2µF DC blocking capacitor. The on-board electret microphone element is connected to the switch terminal on the microphone jack so that it is switched out of circuit when an external microphone is plugged in. Pin 17 of the CODEC provides a low-noise DC output to bias an electret microphone.

This can be connected either via link LK1, labelled BOTH, to both the internal and external microphones or via Link LK2 (labelled INTL) to just the internal microphone.

The CODEC provides a fixed +14dB microphone gain stage followed by an

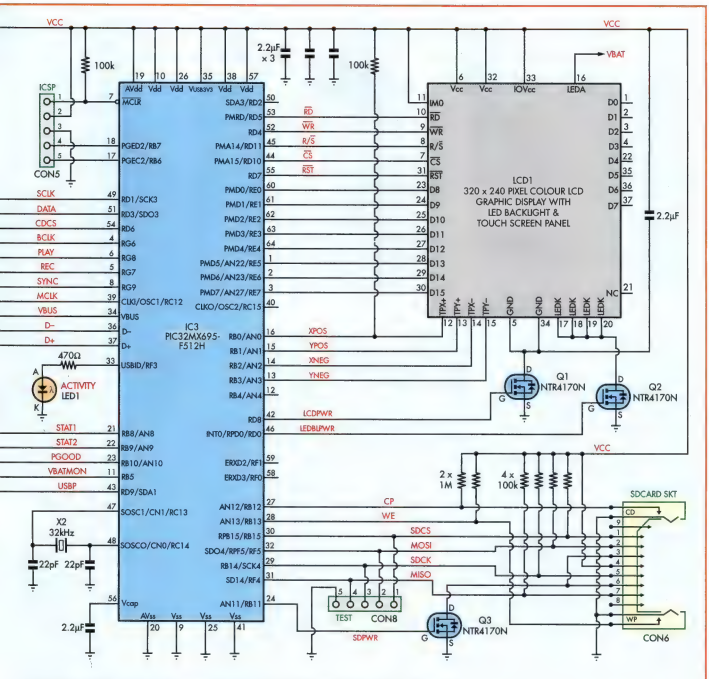


Fig.2: the complete circuit diagram for the Touch-Screen Recorder. It's based on CODEC IC1, PIC micro IC3, touch-screen display LCD1 and an SD card. IC2 (LM3658) provides the charge current to the lithium-ion cell (when the device is connected to a USB port) that's used to power the device. The recorded audio data is stored on the SD card and played back under the control of IC3.

additional +20dB gain stage that can be switched in or out under software control (ie, via the touch-screen). The microphone input can also be muted under software control.

For the audio outputs, the CODEC's internal DACs feed line output buffers that provide fixed-level line outputs on pins 12 & 13. The 2.2µF blocking capacitors prevent any DC bias appearing at the line output jack (CON3), and 100kΩ resistors ensure that the outputs remain referenced to ground. The DAC outputs are also fed to an internal headphone amplifier whose gain is digitally adjustable from -73dB to +6dB in 1dB steps. 100µF blocking capacitors ensure decent low-frequency response, with low-impedance headphones.

If required, the CODEC's audio inputs can be routed to its outputs to provide an analog bypass path. We use this feature to allow monitoring of the signal being recorded. During playback, this bypass function is switched off.

All of the audio circuitry within the CODEC is referenced to a voltage mid-way between the positive supply and ground. This voltage appears at

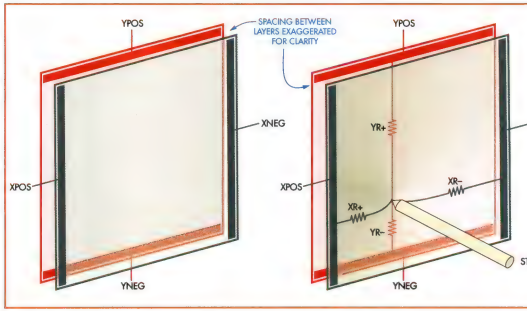


Fig.3: the resistive touch screen is formed using two separated layers of plastic film, each coated with a transparent resistive compound. These effectively form two wide resistors, one in the horizontal (X) direction and one in the vertical (Y) direction. When the screen is pressed, the two films touch and this creates a pair of voltage dividers joined at the point of contact.

the VMID pin of the CODEC (pin 16) and is bypassed by a 100nF capacitor.

The CODEC has four different power supply inputs, two for the digital parts of the circuit and two for the analog parts. The two digital supplies, DVdd (pin 27) and BVdd (pin 1), are connected directly to the 3V rail, as is HPVdd (pin 8), the supply for the headphone amplifier. These are bypassed by a pair 100nF ceramic capacitors and a 100µF electrolytic.

The supply for the analog circuitry, AVdd (pin 14), is derived from the 3V rail (VCC) via a simple RC filter consisting of a 10Ω resistor and a 100nF capacitor. Care has been taken with the PCB layout to ensure that power supplies and ground planes for the analog and digital parts of the circuit are connected so as to minimise the conduction of digital noise into the sensitive analog circuitry.

The digital side of the CODEC consists of a standard digital audio interface on pins 3-7. In our case, the CODEC is configured to be the master. It outputs a bit clock on pin 3 and a frame sync pulse on pin 7.

The frame sync pulse indicates the start of a data frame that consists of the left and then right data words. The bit clock operates at 12MHz or 6MHz, depending on the data rate selected, and the frame rate is equal to the sample rate. For example, at 48ks/s the bit clock rate is 12MHz and the frame rate is 48kHz.

The record data stream from the CODEC appears on pin 6 and the playback data stream from the micro appears on pin 4. Although the CODEC is capable of a number of different word lengths, we use 16-bit words exclusively. If configured correctly, the SPI module in the microcontroller can operate in a framed slave data mode compatible with this data stream – the challenge is to keep the data flowing fast enough so that the audio stream is played or recorded seamlessly.

As mentioned above, a second SPI port is used to configure and control the CODEC. This is a one-way interface on pins 21-24. Connecting pin 22 to VCC selects the SPI mode (the CODEC also supports I^2C for this interface) and the usual chip select, clock and serial data lines are used to receive command data from the microcontroller.

Finally, the CODEC clock is derived from a 12MHz crystal connected to pins 25 & 26, with associated 22pF loading capacitors. The 12MHz clock output from pin 2 drives the microcontroller's clock input to provide the system clock when the microcontroller is awake.

Touch-screen display

As mentioned above, the display is a QVGA colour TFT (thin film transistor) LCD with white LED backlighting. The display incorporates an ILI9341 driver chip configured for an 8-bit or 16-bit parallel interface. This display driver chip contains a large number control registers and a display memory which has one 18-bit data word for each of the 76,800 pixels of the display.

Each 18-bit word defines the 6-bit intensity of each of the red, green and blue sub-pixels, permitting 262,144 colours per pixel. 18 bits is an awkward size to work with given an 8-bit bus, so the display controller allows for the 18 bits to be mapped to a 16-bit word where each pixel is represented by 5 bits or red data, 6 bits of green data and 5 bits of blue data. This is known as 5:6:5 RGB and permits 65,536 colours which is more than sufficient for our application. As we use an 8-bit interface, it takes two write operations to set one pixel of the display.

The display driver connects to the microcontroller through the above-mentioned 8-bit data bus, a chip select line and read and write strobes. A single address line on pin 8 of the display determines whether data is written to or read from the control registers or the display RAM. A reset line allows the microcontroller to reset the display to a known state prior to configuring it.

The backlight is driven by a PWM signal from the microcontroller via Mosfet Q2. As noted earlier, the backlight is fed from the unregulated battery voltage, to maximise the possible brightness and to minimise the power dissipation in the regulator.

Mosfet Q1 is used to disconnect the power entirely from the display in sleep mode. We found this necessary since the sleep current of the display was several tens of micro amps.

Touch-screen operation

The touch-screen is physically integrated with the display but is electrically quite separate. This one is a resistive touch-screen and is formed

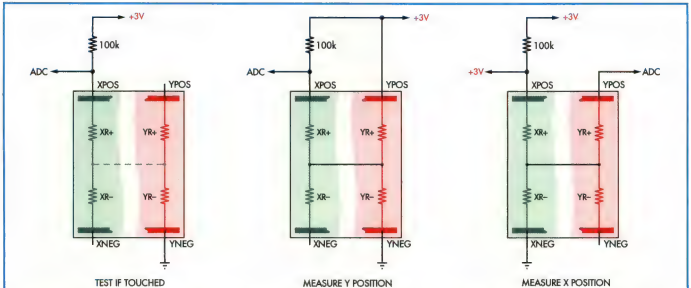


Fig.4: the software polls the touch-screen 100 times per second with the configuration shown at left. If the screen is touched, the ADC will read a low value since the maximum resistance of the touch-screen is much lower than the 100kΩ pull-up resistor. The micro then reads the X and Y positions as shown at centre and right.

from two layers of plastic film, each coated with a transparent resistive compound and separated by a small air gap. One film has conductive bars printed across the top and bottom edges, while the other has conductive bars printed down each side.

The two plastic films effectively form two wide resistors, one orientated in the horizontal (X) direction, and one in the vertical (Y) direction, as shown in Fig.3.

When the screen is pressed with a finger or stylus, the two films touch at the point of contact. This effectively creates a pair of voltage dividers joined at this point. If a voltage is applied between the two X terminals, the voltage measured at one of the Y terminals (while the other is open circuit) will be proportional to the X-coordinate of the touch point. Similarly, if a voltage is applied between the two Y terminals, the voltage measured on one X terminal will be proportional to the Y-coordinate of the touch point.

A bit of scaling and offsetting is required in software. However, it is relatively straightforward to calculate the position of the touch point in terms of the X and Y coordinates of the display pixel on which it occurs. Fig.4 shows how this is done.

Note the 100kΩ pull-up resistor on the XPOS line from the touch-screen. This resistor helps detect when the screen has been touched.

In normal operation, the software polls the touch-screen 100 times per second with the configuration shown in Fig.4 on the left. If there is no touch, the ADC will read a high value. If the screen is touched, the ADC will read a low value, since the maximum resistance of the touch-screen is much lower than the 100kΩ pull-up. If this test shows that the screen is touched, the micro commences the process of reading the X and Y positions as shown in the centre and right of Fig.4.

When the Touch-Screen Recorder is in sleep mode, the ADC is shut down to save power, so we need another way to detect a touch and thus wake the microcontroller. The same configuration of inputs is used as for the touch detection described above but this time the XPOS input pin is configured to provide an interrupt when there is a change of state. Touching the screen changes the normally high level on this input to logic low, triggering an interrupt which wakes the microcontroller.

SD card interface

The SD card socket (CON6) is connected to the third SPI port on the microcontroller, on the righthand side of the circuit. 100kΩ pull-up resistors are used on each of the lines are required by the SD card standard since some cards apparently power up in open-collector mode. Once the SD card is configured, the outputs switch to totem-pole drivers for speed.

The card socket also has switches for detecting the presence of a card and the position of the write-protect slider. These are also connected to the microcontroller via 1MΩ pull-up resistors.

The SD card's ground pins are switched to ground via Mosfet Q3, which is turned on in normal operation. This allows the SD card to be disconnected in sleep mode, since some cards draw as much as 10mA when idle. Mosfet Q3 is also used to "hard reset" the SD card if necessary.

PIC32 microcontroller

The other connections to the microcontroller include the in-circuit programming header (CON5), the 32kHz crystal and associated loading capacitors, the USB data and bus voltage sensing lines from the USB socket (CON7) and a single LED to indicate SD card read or write activity. Other pins are used for control and monitoring of the power supply as described below.

Power supply

The entire circuit, with the exception of the LCD backlight, operates from a 3.0V rail (VCC) derived from the single lithium-ion cell via a low drop-out linear regulator (REG1). This is a Microchip MCP1725 device that can maintain regulation with a drop-out voltage of only 50mV at light load. This is important because the lithium ion cell has a nominal voltage of 3.7V. Fully charged, it produces 4.2V but as it discharges, its output drops to 3.2V or below.

The regulator has an open-collector

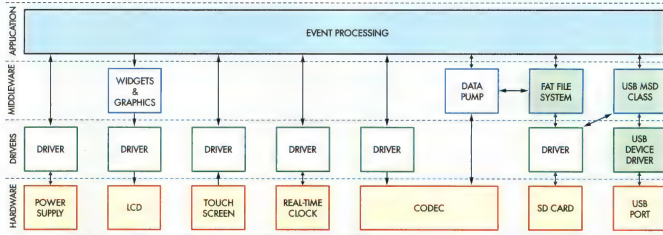


Fig.5: a simplified view of the firmware architecture which is effectively split into three horizontal layers. At the bottom, working directly with the internal peripherals and the external hardware is the "Driver" layer. This is then followed by a "Middleware" layer and then an "Event Processing" layer – see text.

output (PGOOD, pin 5) that pulls low if the regulator output falls below 96% of the nominal 3.0V (at approximately 2.88V). The microcontroller software responds to this by ending any recording or playback in progress and putting the recorder into sleep mode. This is necessary to prevent permanent damage to the lithium ion cell which can occur if it is discharged below 2.7V.

Mosfet Q4 provides polarity protection, against inserting the lithium cell backwards. The cell has a fairly low impedance and could damage the regulator and other semiconductors if inserted wrongly (as we discovered the hard way). A series diode can't be used in this case because the battery has to charge as well as discharge and in any case, we can't really tolerate the relatively high voltage drop of a diode in this circuit.

The Mosfet is ideal for the job because the channel can conduct in either direction if the gate is positive with respect to the source pin. If the cell is inserted backwards, the Mosfet will be off and the body diode will be reverse biased, so no current will flow.

The microcontroller reads the battery level via a voltage divider consisting of two 4.7MΩ resistors. These high values were chosen to limit the current drain of the divider, which is connected across the battery.

The cell itself is charged by IC2, an LM3658 lithium-ion or lithium-polymer charger, designed to run from USB. It uses a complex, multi-stage charging process and can monitor battery temperature, although we don't use this feature.

IC2 also limits the current drawn from the USB port to 100mA or 500mA, depending on the level of the signal on pin 4, to ensure the current drain remains within USB requirements. USB devices are not supposed to draw more than 100mA until they indicate this requirement and are enumerated by the host.

Pins 6 & 7 of IC2 are open-collector status outputs that indicate the charger state. The software reads these inputs and uses the information together with the cell voltage to display the battery status. When not connected to a USB port or charger, the battery indicator displays HIGH, FAIR or LOW to indicate remaining battery capacity.

When the unit is connected to a charging source, the indicator displays CHRG or FULL or ERR to indicate whether charging is in progress, complete or has failed for some reason. The battery charger indicates an error if the battery cannot be charged within a 5-hour period, usually indicating a faulty battery. If this error occurs, the USB power must be removed and restored to reset the battery charger.

Firmware description

The firmware for the Touch-Screen Recorder is relatively complex and a full explanation of its workings is beyond the scope of this article. However, let's provide a broad overview.

Fig.5 shows a simplified picture of the firmware architecture which is split into three horizontal layers. The green shaded boxes indicate pieces of third-party code that were incorporated into the design. At the bottom level, working directly with the internal peripherals and the external hardware is a series of drivers. The aim of these drivers is to hide the device-specific details and provide a programming interface independent of the hardware. Ideally, we could replace the hardware (say by using a different display) and only have to modify the relevant display driver. Similarly, the same display could be used in another project and the driver should be usable without modification.

By way of example, the LCD driver hides the device specific instructions necessary to configure the display driver chip behind a 'C' function that initialises the display. Another function draws a single pixel of a specified colour at a point defined by given X and Y co-ordinates. Other functions are available to draw solid blocks of pixels, to shut down and wake up the display and control the backlight. These functions are exposed to the upper layers in the relevant 'C' header files. All the device specific complexity and any local variables or functions are hidden away within the driver.

Unlike the LCD, some of the drivers have to respond to real-time events (like a touch on the screen). These drivers need some mechanism to let the system know that an event has happened, and the system needs a mechanism to manage and make sense of the unpredictable influx of events.

There are plenty of possible approaches but we have elected to handle this with an event queue. The drivers post events to a first-in first-out (FIFO) queue as they occur. They are dealt

with in turn by the event processor, which we discuss below.

Middleware layer

A middleware layer is used when an advanced level of abstraction is required between the drivers and the application. Continuing our example from above, it would be handy to have a mechanism to draw more complex items on the display, such as lines, shapes, text and icons. These requirements are neither application specific like the top layer, nor are they hardware specific, like the drivers.

The graphics middleware module, for example, calls on the driver functions that draw a single pixel or block of colour and exposes useful higher-level functions. One such function draws a line between any two points in a specified colour or thickness. Another draws proportional width text.

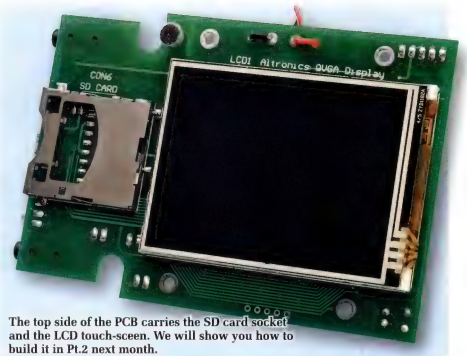
In fact, this module provides routines for drawing filled and empty circles or arcs, rectangles and round-cornered rectangles, for rendering text and drawing icons. Not all of these are used in the Touch-Screen Recorder, since this module was developed for and has been used in other projects.

Also in the middleware layer is the data pump (responsible for shifting data between the CODEC and the SD card), the FAT file system and part of the USB stack. Lets look at these in a bit more detail.

Data pump & file system

In many ways, the data pump is the beating heart of the Touch-Screen Recorder. It has to move data between the CODEC and the SD card at a sufficient rate to avoid glitches in the audio. The CODEC produces (and consumes) data at a rate proportional to the sampling rate, number of channels and the word size. We use a fixed 16-bit data width and two channels, so each audio sample is four bytes long. At 96ks/s we have a data stream of 384,000 bytes per second to contend with.

In contrast, reading and writing files to and from the SD card is a discontinuous process. Data is stored in clusters of 512-byte sectors that may be distributed around the disk in a non-contiguous manner. By the way, the SD card must be formatted with a FAT file system (this is how most cards are formatted out-of-the-box). FAT32, FAT16 and even the older FAT12 formats are supported. Files can be played from or recorded in any directory and file names up to 128 characters are supported.



The top side of the PCB carries the SD card socket and the LCD touch-sceen. We will show you how to build it in Pt.2 next month.

Each recording is made in a new file that is given a unique name based on the date and time. For example a recording made on 16th May, 2014 at 2:57:20pm would be written to a file named REC140516-145720.WAV.

The file system has to consult the file allocation table on the disk to know where to find or place the next cluster of the file being read or written. All of this takes time. Add to this the fact that SD cards are based on flash memory that has a relatively long write time.

When we write to the SD card, the data is actually written into an internal RAM buffer (which is fast) but when this buffer is full, the card must write the contents of this buffer to the flash, a process that can take a few hundred milliseconds or more. The precise time will depend on the write speed of the card and the size of the internal buffer. In general, newer cards are faster than older ones.

Thus, we need to use a pair of internal buffers in the data pump so that one can be filling (to use recording as an example) with data from the CODEC while the other is being written to the SD card. As long as the write time does not exceed the buffer fill time, the system will be ready to write the next buffer as soon as it is filled. If the write time does exceed the fill time, we will find ourselves trying to write and fill the same buffer. This would lead to audible glitches.

The PIC32 microcontroller we have chosen has 128kB of RAM. We found we could allocate up to 96kB of this for the data buffers (two buffers of 48kB each). At the fastest data rate, we fill one of these buffers every 125ms. This is enough to cater to most SD cards. At lower data rates, the SD card write times become less of an issue. At 8ksps, the buffers each take 1.5s to fill.

The data is shifted between the CODEC SPI and the buffers by DMA (direct memory access), so no processor intervention is required in this process. When one buffer is filled or emptied, the DMA unit automatically switches over to fill or empty the other one and an interrupt is generated. Code in the interrupt service routine takes care of reading or writing the data to or from the SD card. The activity LED (LED1) is lit when this is in progress.

The file system used in this project is called FatFS and was developed by a Japanese hobbyist who goes by the online name of ChaN. This free file system is available at http://elm-chan.org/fsw/ff/00index_e.html and has an open license for hobbyist or commercial applications. It has proven to be far more robust, better documented and much faster than other file systems we tried, including one from Microchip.

USB stack

We do, however, use Microchip's

The end panel of the Touch-Screen Recorder provides access to the line input and output sockets, the microphone & headphone sockets, the USB socket and the SD card socket.

USB stack (available free from their website). This consists of a large number of files containing the driver code to control the USB interface peripheral and the higher-level elements of the USB stack necessary to implement a USB Device. In USB-speak, entities can be either a Host (typically a PC) or a Device, like the Touch-Screen Recorder. When first connected, a USB Device makes itself and its capabilities known to the Host through a process called enumeration.

During enumeration, the Device must tell the Host what class of device it is so that the Host can load the appropriate driver. There are a number of standard Device classes for which common operating systems have native drivers. Examples include (1) the Human Interface Device (HID) class for computer mice and keyboards and (2) the Mass Storage Device (MSD) class for hard disks, memory sticks and the like.

The Touch-Screen Recorder is configured to appear as a MSD class Device and so will appear to a Windows, Mac or Linux operating system as an external disk drive.

Interestingly, the USB Mass Storage class does not rely on the Device's file system but rather presents the disk drive to the Host as a SCSI disk and uses the intelligence at the Host end to make sense of the data. The MSD firmware does, however, require the user to provide drivers to handle the basic communication with the media, such as reading or writing a sector.

Fortunately, the requirements of the FAT file system and the MSD system are similar, so only one set of drivers is required. Unfortunately, the MSD stack only ever reads and writes a single sector at a time, whereas the FAT file system makes use of multi-sector reads and writes that are much faster for the bulk transfer of data. This means that data transfer to and from the SD card over the USB interface is relatively slow.

Event-driven programming

At the top level of the architecture, an event manager controls the specific functionality of the Touch-Screen Recorder application. The various drivers and middleware modules post messages to the event queue to signal that some particular event has occurred. The event message indicates the source of the event and any important details. For example, the touch-screen driver posts a message if the screen is touched and includes the X and Y coordinates of the point where it occurred.

In the Touch-Screen Recorder, events are posted by the touch-screen driver (Press, Still Press, Release, Invalid), the SD card driver (SD Inserted, SD Removed), the real-time clock (One Second Tick, Half Second Tick), the data pump (Recording Stopped, Playing Stopped) and the USB driver (Device Disconnected, Device Attached, Device Ready). Many different error events can also be posted, although these are handled in a slightly different way as described below.

After initialising the various subsystems, the main flow of execution enters a loop where it constantly monitors the event queue. Whenever an event is found in the queue, it is popped out and processed by calling the appropriate routines to handle that event type.

Error events are not posted to the queue in the same way as other events, since event processing is serial and there may be several events in the queue ahead of the error event. We don't want to wait until all the pending events are handled before dealing with the error. Using the 'C' standard functions for "non-local jumps" (<setjmp.h>), we can ensure errors are processed immediately they occur.

If any function throws an error, the program flow switches immediately to the event handler, where the error is handled as if it had just been popped out of the queue. There is no need to finish processing the current event or to wait for any pending events.

The event processing architecture provides a very robust and reliable framework for the Touch-Screen Recorder firmware and allows the addition of new functions with minimal chance of 'breaking' anything.

Next month in Pt.2, we will give the assembly details, provide some performance graphs and show how to use and set up the Touch-Screen Recorder. SC

ONLINE & IN STORE

$TOCKTAKE SALE

Rechargeable Camera and Monitor Kit

Multi-purpose camera and monitor kit suitable for virtually any application in the home or car. Suction cup mounting. No wiring required. Recharge with the supplied mains adaptor or cigarette lighter cable.

- 4.3" colour LCD monitor
- 2.4GHz transmission
- IR LED camera

QC-3217 **WAS $139.00**

$119.00 SAVE $20

Spare camera available
QC-3211 WAS $79.95 NOW $69.95 SAVE $10

Peephole Viewer with Image Capture

Displays video from the other side of your door on a clear 3" LCD screen. MicroSD card required for image capture (sold separately **XC-4992 $47.95**) triggered by adding either the knock or PIR sensors (sold separately).

- Requires 2 x AA batteries
- Peephole tube diameter: 12mm
- Peephole tube length: 33 to 45mm
- Viewer size: 158(H) x 87(W) x 32(D)mm

QC-3735 **WAS $225.00**

$199.00 SAVE $26

Optional sensor modules:
PIR Motion Sensor
QC-3736 WAS $84.95
NOW $69.95 SAVE $15
Vibration Knocking Sensor QC-3737 WAS $44.95
NOW $34.95 SAVE $10

Jaycar Electronics
Better, More Technical

2.4GHz Wireless Stereo Speaker System

Stream audio wirelessly from the base station to the rechargeable speakers. Speakers recharge via induction when placed on the base.

- 2 x 3W satellite speakers
- Dock for iPhone®/iPod®
- Built-in Li-ion battery
- Range: up to 30m
- Remote control

AR-1887 **WAS $149.00**

$99.00 SAVE $50

iPhone® not included

HD Car Event Recorder with LCD & GPS

Record vision, audio, GPS coordinates and vehicle speed to a microSD card (sold separately **XC-4992 $47.95**). Play back on its 2.4" colour screen or PC. Built-in G-sensor. Infrared LEDs for night time recording. 720p HD.

- 5MP HD Sensor
- Cycled recording
- 95° wide angle lens
- Microphone
- Video format: H.264/AVI or MP4

QV-3793 **WAS $199.00**

$139.00 SAVE $60

500 Lumen Mini LED Lights

Amazingly bright as well as shock and waterproof. All-round solution for many different applications. Operated from 10-36VDC.

- Spot or flood beam patterns available
- Stainless steel mounting hardware
- Compact size (70H x 70W x 55Dmm)
- Sold individually

Flood SL-3915 $59.95 ea
Spot SL-3916 $59.95 ea

2 FOR $90.00 SAVE $29.90

Class AB Car Amplifier

Ultra-powerful 4-channel amplifier delivers over 100WRMS power per channel. Ideal one amplifier system for powering both full range speakers and a subwoofer.

- 4 x 100WRMS
- RCA inputs
- Gold plated power/speaker terminals

AA-0453 **WAS $229.00**

RESPONSE PRECISION

$199.00 SAVE $30

Economy 4 Channel DVR

Ideal for small surveillance installations with 4 cameras or less and enables simultaneous viewing, playback, recording and backup operations. Supplied with a 500GB SATA HDD, software and manual on CD, power supply, and quick start guide.

- Remote access via Smartphone or web browser
- Built-in web server for network access
- Power supply: 12VDC 3.3A (included)
- H.264 video compression
- Size: 375(W) x 285(D) x 45(H)mm

QV-8120 **WAS $369.00**

SAVE $40 **$329.00**

Also available: **16 Channel DVR QV-8122**
WAS $899 NOW $799 SAVE $100

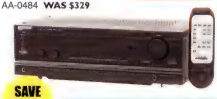
Stereo Amplifier with Remote Control

Higher power with a USB MP3 player function in a standard Hi-Fi component size.

- 2 x 200WRMS channel
- Inputs (analogue): DVD/CD, aux 1&2, phono, tape, USB
- 20Hz - 20kHz frequency
- Size: 430(W) x 241(D) x 114(H)mm

AA-0484 **WAS $329**

$299.00 SAVE $30



3-15VDC 40 Amp Power Supply

High-powered switchmode power supply delivers up to 40 amps. It has a variable output voltage from 3 to 15VDC, or it can be fixed at 13.8VDC. Overload, over temperature and over voltage protection.

- Size: 220(W) x 110(H) x 300(L)mm

MP-3090 **WAS $299.00**

$279.00 SAVE $20

ALL IN ONE SECURITY SOLUTION

No wiring needed! This DVR kit has a solar powered 2.4GHz wireless camera with PIR sensor and 2 x 5W 600 lumen LED lights. Once triggered the lights turn on (if dark) and vision is transmitted wirelessly to the receiver which can be recorded to an SD card (2GB card included) and viewed on your TV.

- Accessories included: mains adaptor, remote control, USB and AV cables
- Up to 90m range
- Motion detection: 15m, 160° wide
- Supports up to 4 cameras.

QC-3644 **WAS $299.00**

$259.00 SAVE $40

Spare camera available separately QC-3646
WAS $199 NOW $179 SAVE $20

SMART OUTLETS

Mains Standby Power Saver

2 FOR $29.90

Saves energy by auto-switching off power to appliances in standby mode.

- IR receiver

MS-6146 **$19.95**

SAVE $10

Remote Controlled Wireless Mains Sockets

Can be programmed to an unused button on a TV or other remote control to turn them on and off. Allows multiple sockets to be controlled from the one button or assign one button per socket. Includes IR receiver units and 2 wireless mains sockets. Includes 2 x AA batteries.

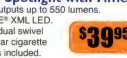
$24.95

- Up to 20m range
- 10A, 2400W rated

MS-6158 **WAS $39.95**

SAVE $15

Spare Wireless Mains Socket
MS-6157 WAS $14.95
NOW $9.95 SAVE $5



240VAC GU10 LED Downlights

Ideal for domestic lighting, shop fittings, or anywhere a bright downlight is required.

2 FOR $19.90

- 4W, 60°
- 24 high output 2835-type SMD LEDs
- 450 lumens

SAVE $10

Cool White
ZD-0546 $14.95
Warm White
ZD-0547 $14.95

ZD-0546

150 Lumens Magnetic Torch

Tough and handy LED worklight perfect for the home, garage or office. Flexible tube & powerful magnetic base. Aluminium build. Requires 3 x AA batteries.

- 3W LED
- Water resistant

ST-3460 **WAS $44.95**

$34.95

SAVE $10

Rechargeable Spotlight with Timer

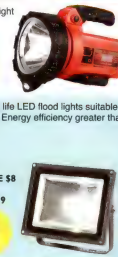
Powerful spotlight outputs up to 550 lumens. Equipped with CREE® XML LED. Digital readout and dual swivel handle. Mains and car cigarette lighter plug chargers included.

$39.95

- 2 x LED map reading light
- Battery type: SLA

ST-3314 **WAS $59.95**

SAVE $20



Dynamo Multifunction Torch

Torch, music player (via USB or SD card), AM/FM radio and Smartphone charger - all in one unit! Wind up/dynamo powered, or use the included rechargeable 1000mAH battery or by 4 x AA batteries (not included).

- Red LED beacon and emergency siren
- 190mm long

ST-3356
WAS $59.95

$49.95

SAVE $10

15% OFF THESE FLOODLIGHTS

High brightness, long life LED flood lights suitable for illuminating a warehouse, automotive workshop, hallway or entry way. Energy efficiency greater than 90%. IP65 rated.

Mains Powered

- Cool white
- 30W 1500 lumens

SL-2879
WAS $64.95

$54.95

SAVE $10

Rechargeable

- Cool white

10W 500 Lumens SL-2887
WAS $49.95 NOW $41.95 SAVE $8
30W 1500 Lumens SL-2889
WAS $119 NOW $100 SAVE $19

FROM $41.95

SAVE FROM $8

Rechargeable with Solar Panel and Motion Sensor

- Cool white
- 10W 500 lumens

SL-2808 **WAS $159.00**

$135.00

SAVE $24

LABORATORY POWER SUPPLIES

13.8VDC Regulated Switchmode

High current general workshop power supply for equipment, component testing etc.

- Input voltage: 190 - 240VAC
- Banana socket style binding posts
- LED power on indication
- Rear mounted M205 fuse

12A MP-3079
WAS $69.95 NOW $49.95 SAVE $20
40A MP-3089
WAS $199.00 NOW $149.00 SAVE $50

FROM $49.95

SAVE FROM $20

0 to 32VDC 0 to 3A Regulated Variable

Provides stable voltage and current with a regulated output voltage. Uncluttered control panel with LCD meter, voltage and current adjustment knobs.

- Large backlit LCD display
- Weight: 6.5kg
- Size: 130W x 160H x 320D(mm)

MP-3086
WAS $199.00

$149.00

SAVE $50

1 TO 16VDC 0 to 40A Regulated Switchmode

Features a variable output voltage from 1 to 16VDC and variable current from 0 to 40A with a dual action (coarse/fine) microprocessor controlled rotary enooder tuning for smooth, precise and fast settings.

- Weight: 2.6kgs
- Size: 200(W) x 90(H) x 215(L)mm

MP-3094 **WAS $399.00**

$349.00

SAVE $50

20% OFF MAINS ADAPTORS

5W Switchmode Plugpack Unregulated

Direct replacement for old transformer type AC adaptors. Ultra slim design.

- Input: 100-240VAC, 50/60Hz
- Unregulated output voltage
- Supplied with 7 plugs
- Safety approval no.: NSW22823
- MEPS compliant

9VDC 0.55A MP-3280
WAS $14.95
12VDC 0.4A MP-3282
WAS $14.95

$11.95 ea

SAVE 20%

Switchmode Plugpacks with USB

Slim, lightweight and feature manually selectable variable voltage outputs.

- Input: 100 - 240VAC
- Supplied with 7 plugs and USB output socket
- Approval no.: SAA091002EA
- MEPS compliant

18W 1500mA (max) 3-12VDC MP-3314
WAS $29.95 NOW $23.95 SAVE 20%

27W 2250mA (max) 3-12VDC MP-3316
WAS $34.95 NOW $27.95 SAVE 20%

Travel Adaptor

Handy for charging USB devices without needing to connect the device to a computer. Suitable for iPhone® and latest generation iPod® products.

- Input: 100 - 240VAC, 50/60Hz
- Output voltage: 5VDC
- Output current: 1A max
- Approval no.: V09011

MP-3452 **WAS $19.95**

$15.95

SAVE 20%

Savings off original RRP Limited stock on sale items

SAVE OVER 20% ON BATTERY ACCESSORIES

Dual Battery Isolators with Adjustable Disconnect/Reconnect

Allows both batteries to charge whilst your engine is running, but keeps your main engine battery isolated from being discharged by your 12V accessories once camped.

FROM $79.00

- Extremely low standby current and voltage drop
- 10 user adjustable set points for disconnect & reconnect voltages
- Over current, over voltage and over temperature protection
- Emergency over-ride feature

SAVE FROM $20

12VDC MB-3680 WAS $119.00 NOW $94.00 SAVE $25
24VDC MB-3682 WAS $99.00 NOW $79.00 SAVE $20

4 Stage 40A DC to DC Boost Charger

Voltage drop is a big issue in many dual battery systems but not with this charger! It's capable of taking an 8-16VDC input, and boosting the voltage to 13.6V/14.4V. 4-stage battery charging output. Output current is rated at 40A to ensure a quick charge.

$229.00

- Size: 260(L) x 140(W) x 80(H)mm MB-3690 **WAS $299.00**

Also available:
4 Stage 40A 24V to 12V DC to DC Battery Charger MB-3691 WAS $299.00 NOW $229.00 SAVE $70.00

SAVE $70

SLA Battery Charger

Suitable for use with 6 and 12 volt batteries. Built-in polyswitch for over current and polarity protection. Supplied with 2.1mm DC plug and a lead with battery clips.

SAVE $10

- Approval no.: N19309
- 1.8A charging MB-3523 **WAS $29.95**

$19.95

500A Battery Isolation Switch

High current rated battery isolation switch for high power applications. Often fitted to boats, trucks, motor homes and other battery based power systems to allow quick and easy electrical isolation of the battery for protection against discharge, fire and other safety risks.

- M12 brass bolt terminals
- Metal body
- 12V
- Continuous rating (6-48VDC): 500A
- Max rating (6-48VDC): 2000A (10 sec.) SF-2247 **WAS $49.95**

SAVE $10

$39.95

Dual Battery Volt/Current Monitor

Don't let your battery run flat ever again! Ideal for boats or caravans/RVs, especially when running refrigeration products or lighting. It is mounted with a single hole, suitable for bulkheads up to 27mm thick. 250A current shunt supplied.

- Audible warning below 11.5V or over 15.5V MS-6176 **WAS $149.00**

$119.00

SAVE $30

9 STEP SWITCHMODE BATTERY CHARGER

Nine step fully automatic 25A high current charger with maintenance charging of all types of lead-acid batteries (SLA, Gel and AGM) as well as lead-calcium batteries from 50 - 500Ah, either 12V or 24V. The electronics are fully microprocessor controlled and protected against user error, so is totally safe to leave connected for months at a time. Perfect for caravan and boat users. See our website to download full product info sheet.

- IP44 Rated
- Input: 170 - 260VAC
- Current: 4A max
- Size: 260(L) x 135(W) x 70(H)mm MB-3608 **WAS $399.00**

$319.00

SAVE $80

Reversing Camera with Sensors & 3" LCD Monitor

Scans the rear of the vehicle for any object within the detection range appearing on the monitor with changing tones. System includes four sensors, a camera, and a 3" TFT LCD monitor.

$179.00

SAVE $20

- PAL or NTSC mode available
- Power: 12VDC
- Anti-false alert technology LR-8870 **WAS $199.00**

400A Stainless Steel Battery Clamps

All metal parts are made from 316 marine grade stainless steel, they can be taken and used anywhere without the risk of corrosion. Rated 400A.

SAVE $6

- Sold as a pair HM-3086 **WAS $12.95**

$6.95

SLA Battery Boxes

Designed to suit larger SLA batteries or your standard car battery. Perfect for mounting in your boat, trailer or caravan. Includes mounting clamps and lid strap to secure the box properly in place.

FROM $19.95

To suit 40Ah SLA Batteries HB-8100 WAS $24.95 NOW $19.95 SAVE $5

To suit 100Ah SLA Batteries HB-8102 WAS $29.95 NOW $23.95 SAVE $6

SAVE FROM $5

6 x 9" Kevlar Coaxial Speaker

Clean, crisp and maintains a natural and smooth balanced sound with the silk dome tweeters.

RESPONSE PRECISION

- 75WRMS, 4 ohms
- Sold as a pair CS-2403 **WAS $119.00**

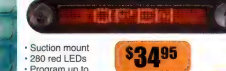
$99.00

SAVE $20

Other sizes available in store/online.

LED Scrolling Message Sign

Attach this to the rear window of your car (or any window) to display messages. Remote control included. 12VDC via cigarette lighter socket.



- Suction mount
- 280 red LEDs
- Program up to 10 messages at 80 characters each
- Size: 300(L) x 50(W) x 10(D)mm XC-0201 **WAS $49.95**

$34.95

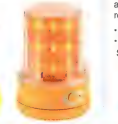
SAVE $15

Signal Strobe Light

Suitable for emergency situations. Includes 36 high brightness LEDs positioned behind orange lenses. Strong magnetic base for mounting to cars, boats or trucks. O-ring sealed.

- Requires 2 x D batteries
- Size: 146(H) x 114(Dia.)mm ST-3234 **WAS $39.95**

$34.95



SAVE $5

Bicycle LED Indicator Kit

Keep your eyes on the road and turn safely using our bicycle indicator kit. Control unit mounts to the handle bars and the indicator mounts on the seat base. Audible beeps confirm your choice of direction and has a hazard light function for road-side emergencies.

- Waterproof
- Requires 3 x AAA batteries ST-3227 **WAS $29.95**

$24.95

SAVE $5

HDMI Splitters with 3D and 4Kx2K Support

FROM $59.95

Share the latest HD movies, TV shows, music videos, corporate videos from a Blu-Ray player, HD media player or digital set top box across multiple displays. Feature stunning 3D content and support for 4Kx2K resolution. Power supplies included.

SAVE $10

2 Port (Shown)
AC-1700 WAS $69.95 NOW $59.95 SAVE $10
In store ONLY. Limited stock. Not available online.

4 Port
AC-1702 WAS $99.00 NOW $89.00 SAVE $10
Limited stock.

HDMI Audio Signal Volume Leveller

$79.00

Sorts out those annoying fluctuations in volume while channel surfing or between the TV shows themselves and the advertisements.

SAVE $20

- Mains power supply included
- HDMI in/out ports

AC-1615 **WAS $99.00**

Rechargeable In-Ear Stereo Bluetooth® Headset

$64.95

Durable and lightweight. Suitable for casual or sports use. The cable wraps around behind your neck staying clear of your arms as you exercise.

- 10Hz - 20kHz
- 54mm long

AA-2069
WAS $74.95

SAVE $10

Portable Stereo Speakers/Charger

Suitable for use in a small room or on the go. Enjoy high quality stereo sound from your personal media device. Requires 4 x AA batteries.

- Dual 2" full range drivers
- 2W per channel
- AC/DC adaptor for standalone charging
- Size: 256(W) x 115(H) x 70(D)mm

AR-1989 **WAS $59.95**
Note: iPhone® not included

$44.95

SAVE $15

GET THE PARTY STARTED!

Snow Machine

Create a winter wonderland anywhere! Produces a jet of small foam balls which float majestically to the ground like real snow. Foam dissolves slowly leaving minimal residue.

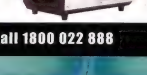
$79.00

SAVE $20

- 240VAC operation
- 1.3L fluid capacity
- 1L snow juice lasts approx 20 min.

AF-1216
WAS $99.00

1L Snow juice sold separately (AF-1217) $9.95



Analogue to Digital Audio Converter

$49.95

Converts 2 x RCA stereo audio inputs to S/PDIF TOSLINK optical and S/PDIF RCA coaxial outputs. Perfect for connecting devices that lack digital audio to speaker systems which only accept digital audio.

SAVE $10

- Power supply included

AC-1596
WAS $59.95

4 Input HDMI Switcher

$79.00

Allows you to expand your HDTV system and connect multiple devices such as game consoles or DVD players to a single HDMI input.

- HDMI 1.4a compliant
- Supports 3D, HEAC, and CEC
- 4 x HDMI inputs, 1 x HDMI output
- Ethernet Port

AC-1619 **WAS $99.00**

SAVE $20

In store ONLY. Limited stock. Not available online.

Pro Monitor Headphones

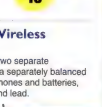
$89.00

Provides accurate, linear sound reproduction to cater for the most demanding monitoring applications. Comfortable ear cushions for fatigue-free listening.

- 10Hz - 26kHz
- Driver diameter: 42mm

AA-2065 **WAS $99.00**

SAVE $10



Dual Channel UHF Wireless Microphone System

Two-channel system supporting two separate microphones. Each channel has a separately balanced XLR output. Includes two microphones and batteries, receiver unit, 14VDC plugpack and lead.

- 4W, 40Hz - 18kHz
- Wireless range: 60m

AM-4078
WAS $149.00

$119.00

SAVE $30

In store ONLY. Limited stock. Not available online.

2 Channel Pro DJ Mixer

The ideal mixer to learn on. Two channels each with RCA inputs for CD or other line level source and a set of phono inputs.

$129.00

- BPM counter
- Level meters on each channel
- 2 band EQ on each channel
- Mic and headphone outputs
- Effects loop
- Line level preamp outputs

AM-4206 **WAS $149.00**

SAVE $20

2.4GHz Wireless Audio Amplifier System

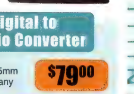
$94.00

Send crystal clear 2.4GHz audio from your Hi-Fi or portable music device to speakers up to 20m away without messy wiring.

SAVE $35

- Power output: 15WRMS x 2 (into 4 ohms)
- 3.5mm input
- Tx/Rx requires 8 x AA batteries each

AR-1895 **WAS $129.00**



AC3 and DTS Digital to Analogue Audio Converter

$79.00

Accepts input via RCA coaxial, 2 x SPDIF, or 3.5mm stereo audio and output any of them to 5.1 channel analogue (6 x RCA). For audio enthusiasts who demand highest level of conversion.

SAVE $20

- 24-bit audio DSP
- Supports Dolby Digital

AC-1634 **WAS $99.00**

IR Remote Control Extender

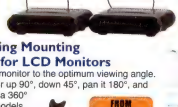
Allows you to control your video source devices like Foxtel, a set top box, Blu-Ray/DVD player, or even a HDMI switcher from another room.

- Foxtel iQ2 compatible
- Up to 50m range
- Power supply: 9VDC/150mA

AR-1827 **WAS $49.95**

$39.95

SAVE $10



Articulating Mounting Brackets for LCD Monitors

Position your monitor to the optimum viewing angle. Tilt the monitor up 90°, down 45°, pan it 180°, and rotate around a 360° range. Both models conform to the standard VESA mount.

FROM $64.00

- Suits monitors up to 27"
- Capacity: 3.2 - 8.1kg

WALL MOUNT CW-2873
WAS $89.00 NOW $64.00 SAVE $25

DESK MOUNT CW-2872 (Shown)
WAS $99.00 NOW $69.00 SAVE $30

SAVE FROM $25

2 Channel MIDI Mixer

Mix, play and scratch your own MP3 tracks directly from your PC. The mixer sends MIDI data from the controller to your DJ software without the inconvenience of mouse control. Fully class-compliant USB MIDI device complete with Virtual DJ software.

$229.00

- Portable
- 2-deck controller
- Mix 2 files in 1 controller
- USB powered

AM-4252
WAS $249.00

SAVE $20

V8 Wireless Doorbell

Switchable sounds between a revving V8, a screaming F1 racer, a roaring super bike or sedate ding-dong.

SAVE $5

$24.95

- 30m range
- Mains adaptor and mounting hardware included
- Requires 3 x AA batteries

LA-5000 **WAS $29.95**

Solar Powered Magnetic Entry Alarm

Cost-effective and simple security measure.

- Warning sticker included
- No wiring
- Solar cell keeps the built-in battery charged
- Self-adhesive

$14.95

SAVE $5

LA-5005 **WAS $19.95**

Also available:
Solar Powered Mini Window Alarms
LA-5003 WAS $19.95 NOW $14.95 SAVE $5.00

Wi-Fi Inspection Camera

Inspect the inaccessible with this 1.8" colour CMOS camera. Uses your Smartphone as the screen. Power supply, bracket, hook and metal adaptor included.

$129.00

SAVE $20

- IP67 rated camera
- 685mm flexible gooseneck
- 50m range

QC-3351 **WAS $149.00**

iPhone® not included

Water Leakage Alarm

This unit will alarm when it detects a water leak, making it ideal for areas prone to flooding or leaks. Built-in magnet for easy mounting to metal surfaces.

$7.95

- Loud 120dB siren
- Battery test button
- Low battery indicator
- Built-in magnet
- Weather resistant sensor
- 2 x AAA alkaline batteries required

LA-5163 **WAS $9.95**

SAVE 20%

Non-Contact Infrared Door Exit Switch

This infrared sensor can replace the old push button switch on automatic exit doors so that they will open with just a wave of your hand.

- 12VDC supply voltage
- 3A @ 30VDC contact rating
- 30mm sensor diameter

LA-5187 **WAS $59.95**

$49.95

SAVE $10

2.4GHz Wireless Baby Monitor

Transmits audio wirelessly up to 50m using 2.4GHz transmission. Features a night light and five pre-programmed lullabies. Equipped with rechargeable docking station.

- Backlit LCD display screen
- Built-in mic and speaker
- Talk button key
- Mains power supply included

$49.95

SAVE $20

QC-3261
WAS $69.95

2.5" LCD Video Doorphone with RFID Access

Suitable for home use, or areas requiring access identification/authorisation. Consists of an outdoor camera with door bell/entry button as well as RFID access and a separate indoor 2.5" LCD for easily identifying visitors. Door locks are available separately to remotely lock/unlock the door. Cat5/6 cable required between camera and monitor.

- 2.5" colour LCD
- Master RFID tag, delete & slave tag included
- Power supply included

SAVE $20

$229.00

QC-3822 **WAS $249.00**

Motion Activated Time Lapse HD Camera

Takes photos whenever it detects movement and creates a time lapse video to playback later on a PC. Captures 30 frames in 30 seconds

- 1280 x 720 resolution (AVI format)
- Waterproof camera
- Detection distance: 4m
- Supports up to 16GB SDHC (not included)

$179.00

SAVE $20

QC-8032 **WAS $199.00**

Intelligent GSM Wireless Alarm System

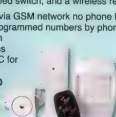
Incorporates a quad band GSM module which provides phone and SMS notification (GSM SIM card not included) when the alarm is triggered. Supplied with alarm control unit, power supply, 120dB siren, wireless PIR detector and wireless reed switch, and a wireless remote control.

- Alarm trip notification via GSM network no phone lines required
- Notifies up to three programmed numbers by phone and SMS
- Wireless range of 50m
- Up to 9 separate zones
- Standby battery: 9VDC for 15hrs back-up

SAVE $20

LA-5156 **WAS $299.00**

$279.00



Dummy Dome Camera

Tough plastic dome camera which looks just like the real thing. "L" type camera and can be placed in any right-angled side edge.

- Plastic bracket

$14.95

LA-5311
WAS $19.95

SAVE $5

Limited stock.

External Camera Housing with Built-in Heater

This weatherproof enclosure is ideal for adapting our professional range of CCD video cameras for commercial outdoor use.

SAVE $10

- Aluminium
- Internal heater
- Clear glass window
- Removable sunshade

$39.95

QC-3331 **WAS $49.95**

In store ONLY. Limited stock. Not available online.

Vari-focal Lenses for Day / Night Cameras

These high grade lenses are constructed from ED (extra-low dispersion) glass elements for greatly enhanced low light performance and improved picture quality. Especially suited to our professional type ExView and day / night cameras.

Aspherical 3.0 - 8.0mm
QC-3353 WAS $129.00 NOW $99.00 SAVE $30
In store ONLY. Limited stock. Not available online.

FROM $79.00

4.0 - 15.5mm
QC-3355 WAS $99.00 NOW $79.00 SAVE $20

5.0 - 50.0mm
QC-3356 WAS $129.00 NOW $99.00 SAVE $30

SAVE FROM $20

600TVL Hidden Camera Mirror

Looks like a simple convex security mirror but embedded behind is a 600TVL security camera.

- 12VDC required - use MP-3011 $19.95
- Image sensor: 1/3" colour CCD
- Size: 350(Dia.) x 200(H)mm

$139.00

SAVE $60

QC-8631 **WAS $199.00**

Bullet Style CCD Camera

Weatherproof camera with 70° viewing angle. 1/3" Panasonic CCD sensor. Supplied with adjustable mounting base and leads.

- 380TV line
- 2.1mm DC connector
- 12VDC required - use MP-3011 $19.95

$79.00

SAVE $20

QC-3488 **WAS $99.00**

6-Way Membrane Switch Panel with Relay Box

$89.95

SAVE $10

An ultra compact 6-way 12VDC touch control panel to control devices in automotive, camping, or marine applications. Waterproof (IP67 rated) on the switch panel.

- Built-in resettable fuses
- Max current: 10A per channel, 35A total

SP-0900 **WAS $99.95**

Digital Frequency Counter

2.7GHz dual range frequency counter for measuring functions of frequency, period totals and self check. Large 10mm high intensity 7 segment LED display. Data hold function. ABS case.

- Frequency range: 10Hz - 2700MHz
- 8 digit LED

QT-2202 **WAS $169.00**

SAVE $30

$139.00

In-Store Only. Limited Stock. Not available online.

DIY TOOLS

Ergonomic Supercrimp Tool

Designed to perform the same tasks as a normal crimper, but with 40-50% less handle-force required.

$49.95

- Heavy duty
- Interchangeable dies (sold separately)

TH-1950

SPECIAL!
PURCHASE TH-1950 & GET A FREE DIE OF YOUR CHOICE VALUED AT $17.95 (Available dies: TH-1952, TH-1953, TH-1954, TH-1955, TH-1956, TH-1957, TH-1958. See website for details)

Pro Quality Instrument Cases

FROM $11.95

SAVE 20%

Great for test instruments and other high grade projects.

Small - Non Vented
HB-5912 WAS $14.95
NOW $11.95 SAVE 20%

Large - Vented
HB-5910 WAS $18.95
NOW $14.95 SAVE 20%

Braided Hook and Loop Loom Wrap

FROM $9.95

Wraps around your cables and secures them with hook and loop.

1.5m 32mm
WH-5654 WAS $14.95
NOW $9.95 SAVE $5

1.5m 51mm
WH-5656
WAS $17.95
NOW $12.95
SAVE $5

SAVE $5

Automotive Relay

$9.95

150A contacts for ultra high power applications such as multiple lights, high power audio etc, in a small package.

- SPDT
- 150A, 12VDC
- 50 ohms, 240mA

SY-4073 **WAS $14.95**

SAVE $5

Dynamo-Powered DMM

Crank the handle for 10 seconds to provide power for approx 10 minutes operation. No batteries required. Cat III. 10A current.

- Data hold
- Capacitance and frequency

QM-1547
WAS $39.95

$19.95

SAVE $20

In-Store Only. Limited Stock.

Compression Crimping Tool

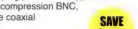
A precision crimp tool that employs a ratchet action ensuring correct crimping pressure is applied for reliable, trouble-free compression BNC, RCA, PAL and F-type coaxial connectors.

SAVE $10

- Adjustable compression depth

TH-1801 **WAS $59.95**

$49.95



Limited stock. HURRY!

Fuse Gang Blocks

Ideal for low voltage applications.

FROM $6.95

- 4 & 6 way with power/ earth bus
- Accepts 3AG type fuses
- Plated screw terminals
- Both can be safely screwed to a metal surface (low voltage only)
- 15A max

SAVE 30%

4 Way
SZ-2006 WAS $9.95
NOW $6.95 SAVE $3

6 Way
SZ-2007 WAS $12.95
NOW $8.95 SAVE $4

Drill Assistant

Drill holes in walls easily, on the level and with no mess! Combination of laser leveler and drill dust collector lets you finish jobs in minutes.

- Requires 2 x AA batteries

TD-2151
WAS $19.95

$14.95

SAVE $5

DIY Coax Tool

This handy tool cuts, strips and crimps RG-58, RG-59 and RG-6 cables and connectors.

TH-1875 **WAS $11.95**

$7.95

SAVE 30%

Metal Enclosures

Aluminium case finished in grey with black finish steel cover. Ventilated and supplied with rubber feet.

- 102(D) x 53(H) x 83(W)mm
  HB-5441 WAS $9.95 NOW $7.95 SAVE 20%
- 150(D) x 61(H) x 102(W)mm
  HB-5442 WAS $13.95 NOW $10.95 SAVE 20%
- 150(D) x 76(H) x 134(W)mm
  HB-5444 WAS $14.95 NOW $11.95 SAVE 20%
- 184(D) x 70(H) x 160(W)mm
  HB-5446 WAS $19.95 NOW $15.95 SAVE 20%

SAVE 20%

FROM $7.95

Multi-Filament Zipper Wrap

Tame messy cables! Simply insert the cable and do up the zip. Double filament for extra strength and durability.

FROM $14.95

1.5m 30mm
WH-5661 WAS $19.95
NOW $14.95 SAVE $5

1.5m 50mm
WH-5663 WAS $29.95
NOW $24.95 SAVE $5

SAVE $5

Heavy-Duty PVC Tape

Cordon off hazardous areas or create an unmistakable marker with this heavy duty PVC tape.

- 33m roll

NM-2864 **WAS $9.95**

$4.95

HALF PRICE!

Large Anti-static Workplace Mat

Covers the whole top of a desk or work station. Grey in colour and made of anti-static foam plastic.

- 1m x 0.5m x 3mm thick

TH-1784 **WAS $39.95**

$29.95

SAVE $10

IR Light Barrier Kit

$29.95

SAVE $10

Consists of an infrared receiver and transmitter and will shoot an IR beam 18 metres. Use with driveway or pathway monitoring, automatic garage door triggering or shop front/office entry monitoring.

- TX requires 9VDC 90mA; RX 12VDC 100mA

KG-9096
WAS $39.95

miniMaximite Controller Kit

Ref: Silicon Chip Magazine Nov 2011

Versatile and intelligent controller to interface with your creations, such as home automation. Features 20 configurable digital/analogue I/O ports, 128k RAM and 256kB flash memory to hold your program and data.

$44.95

SAVE $5

- Kit supplied with PCB, pre-programmed and pre-soldered micro, and electronic components
- PCB: 78 x 38mm

KC-5505 **WAS $49.95**

USB Port Voltage Checker Kit

Ref: Silicon Chip Magazine July 2013

An easy way to test a USB port to see if it is dead, faulty or incorrectly wired to help prevent damaging a valuable USB device you plan to connect. Voltage is indicated using three LEDs. Kit supplied with double sided, solder masked and screen-printed PCB.

$24.95

SAVE $5

- PCB: 44 x 17mm

KC-5522 **WAS $29.95**

Do Not Disturb Phone Timer Kit

Ref: Silicon Chip Magazine May 2013

Stop intrusive phone calls when you don't want to be disturbed. Set the timer duration to one of five settings between 15 to 120 mins and the caller will get an engaged signal until the timer times out.

$24.95

SAVE $5

- Kit supplied with silk-screened PCB, black enclosure.

KC-5521 **WAS $29.95**

USB Power Monitor Kit

Ref: Silicon Chip Magazine Dec 2012

Plug this kit inline with a USB device to display the current that is drawn at any given time. Displays current, voltage or power. Auto-ranging and will read as low as a few microamps and up to over an amp. Kit supplied with double sided, solder masked and screen-printed PCB with SMD components pre-soldered, LCD screen, and components.

Laptop not included

$49.95

SAVE $10

- PCB: 65 x 36mm

KC-5516 **WAS $59.95**

12V 120W 3-Step MPPT Solar Charger Kit

Ref: Silicon Chip Magazine February 2011

Designed for use with 40W to 120W 12V solar panels and lead acid batteries and provides 3-stage charging with the option of equalisation and with MPPT (Maximum Power Point Tracking). Operation is for 12V panels and batteries. Kit includes PCB, all components and case.

$99.00

SAVE $30

- Charge indicator LEDs
- Temperature compensation for charge voltage
- 3-step charging
- PCB: 111 x 85mm

KC-5500
WAS $129.00

Jacob's Ladder High Voltage Display Kit MK2

Ref: Silicon Chip Magazine April 2007

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone.

$34.95

SAVE $8

- Includes PCB, pre-cut wire/ladder and all electronic components
- PCB: 170 x 76mm

KC-5445 **WAS $42.95**

IR Remote Extender MKII Kit

Ref: Silicon Chip Magazine October 2006

Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device.

$19.95

SAVE $7

- Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components
- Requires 9VDC and 2-wire cable for extending the IR-Tx lead (use **WB-1702 $0.50/m**).
- PCB: 79 x 47mm

KC-5432 **WAS $26.95**

Mains Timer Kit for Fans and Lights

Ref: Silicon Chip Mag August 2012

This simple circuit provides a turn-off delay for a 230VAC light or a fan, such as a bathroom fan set to run for a short period after the switch has been turned off. The circuit consumes no stand by power when load is off. Kit supplied with PCB, case and electronic components. See website for a list of alternate capacitors for different time periods.

$29.95

SAVE $10

- PCB: 60 x 76mm

KC-5512 **WAS $39.95**

Kits for Kids

Remote Control Robot Kit

Includes a collection of components ready to assemble, once complete you will have a fully remote controlled robot unit.

$19.95

SAVE $10

- Suitable for ages 8+
- Requires 6 x AAA batteries in total

KJ-8952 **WAS $29.95**

Remote Controlled Tank Kit

Includes the chassis, 2 x tracks, the hull, a turret, 2 gun tubes, one gun support and all the wheels. Assemble the pieces and you will have a fully functioning tank ready to roll out!

$19.95

SAVE $10

- Suitable for ages 8+
- Requires 6 x AAA batteries

KJ-8950 **WAS $29.95**

3-in-1 All Terrain Tracked Robot Kit

A robust all terrain tracked robot kit with detailed instructions included. Comes with 6 terrestrial tracks/crawlers. Can be reconfigured to operate as a gripper, rover or forklift type mechanism. Electric motors included.

$39.95

SAVE $10

- Suitable for ages 13+
- Requires 4 x AA batteries

KJ-8918 **WAS $49.95**

6-in-1 Solar Educational Kit

Build any one of six different projects (windmill, car, dog, plane, airboat, revolving plane). No tools, soldering or glue required. All the parts snap together with spring terminals for the wiring.

2 FOR $9.95

HALF PRICE!

- Suitable for ages 10+

KJ-8926 $9.95

Amazing Soccer Fever Educational Science Kit

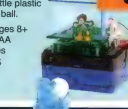
This kit consists of a goal keeper and a little plastic foot to kick the ball.

2 FOR $9.95

HALF PRICE!

- Suitable for ages 8+
- Requires 2 x AA (LR6) batteries

KJ-8949 $9.95



Educational FM Radio Kit

Allows kids to build their very own FM radio! No soldering required.

$19.95

SAVE $10

- Suitable for ages 8+
- Requires 2 x AA batteries

KJ-8915
WAS $29.95

USB Hard Drive Dock

Allows you to store and access files on your network or across the Internet using a web browser or Smartphone. Ultra fast USB 3.0 connection. Docks your SATA hard drive so that it can be set-up for Samba, WebDAV, FTP or media. Also add and download torrents using this device.

- Supports 3.5/2.5 inch SATA hard drives
- Size: 134(L) x 114(W) x 55(H)mm

XC-4691 **WAS $119.00**

Note: HDD not included, and requires freely available third-party app for Smartphone support.

$99.00

SAVE $20

24 Port Ethernet Switch

- 24 x 10/100 Ethernet ports
- Auto-negotiation & auto MDI/MDIX support
- Dynamic buffer limiting
- Mains adaptor included

YN-8083 **WAS $99.95**

$89.95

SAVE $10

2 Port KVM Switch

Control 2 computers with one keyboard and mouse. Will also share stereo audio and mic so only one set of speakers/mic is needed.

- 1 x input cable with 2 x HDMI, 2 x USB and 2 x 3.5mm plugs
- 3 x HDMI to DVI adaptors included (1 for monitor, 2 for PCs)

YN-8094 **WAS $119.00**

$99.00

SAVE $20

USB 2.0 Smart Transfer Cable

Quickly transfer files between PCs, MACs, and even Android® devices. Fully plug and play for Windows and MAC® computers.

- 2 metres

XC-4949 **WAS $49.95**

$39.95

SAVE $10

Notebook Cooling Pad

Plugs into a notebook's USB port and has a built-in 18cm cooling fan to dissipate heat. Quiet.

- Four non-slip pads
- Tilted surface

XC-5210 **WAS $12.95**

SAVE 20%

$9.95

Bluetooth® Foldable Keyboard

Folds to half its size from 285mm to 133mm long for easy storage.

- Powered by 1 x AAA alkaline battery (included)

XC-5202 **WAS $39.95**

$29.95

SAVE $10

Mini USB Power Bank

- Charge most modern portable gadgets when away from mains power
- 2200mAh
- Included adaptors: 30-pin Apple®, 2mm, Mini-B USB, Micro-B USB

MB-3645 **WAS $24.95**

$19.95

SAVE $5

Near Field Audio Wireless Speaker

Place your Smartphone or iPod Touch® on top of this speaker to wirelessly amplify the music playing from its loudspeaker. Powered either by batteries (not included) lasts up to 15 hrs or via USB.

- Output: 2 x 2WRMS
- 3.5mm audio jack
- 5VDC power in

XC-5220 **WAS $39.95**

$29.95

SAVE $10

USB Car Chargers

Simply plug into the car's cigarette lighter socket to fast charge your Apple® devices while driving. Both units include a USB charging cable to suit iPad®/iPhone®/iPod®.

Single (2.1A) (shown) MB-3657
WAS $24.95 NOW $19.95 SAVE $5

Double (2.1A, 1.0A) MB-3658
WAS $29.95 NOW $24.95 SAVE $5

FROM **$19.95**

SAVE $5

Wi-Fi Extender - Ceiling Mount

A high-speed solution for broadening coverage and eliminating dead spots in a home or office Wi-Fi setup. Fully compatible with 802.11n protocol. Speeds up to 300Mbps and functions as an access point and repeater at the same time.

- 5VDC power supply included

YN-8362 **WAS $99.00**

$79.00

SAVE $20

iPhone® not included

YOUR LOCAL JAYCAR STORE - Free Call Orders: 1800 022 888

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Mandurah Ph: (08) 9586 3827
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Northbridge Ph: (08) 9328 8252
Rockingham Ph: (08) 9592 9000

Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Savings off Original RRP.
Prices valid from 24th May 2014 to 22nd June 2014.

Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock.

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PRODUCT SHOWCASE

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SERVICEMAN'S LOG

Resurrecting a faulty car key fob

Dave Thompson*

A faulty car key fob can be a real problem if you don't have a spare and the car is an old model. The fob is linked to the car's ECU and if you can't get it fixed or get a new one programmed, the car isn't going anywhere.

Recently a bloke dropped into the workshop with a problem he was hoping I could solve. I had already made virtual acquaintance with this guy on an online forum where enthusiasts of the MG car model I drive meet to swap knowledge and information.

Online forums (or fora for the pedants or ancient Romans among you) have sprung up all over the web and are an amazing resource many internet users are only now discovering. They offer a wealth of knowledge on just about every hobby, occupation, interest (or fetish) under the sun and are usually free for everyone, although donations are sometimes sought to help meet hosting costs and other expenses.

In the MG forum I follow, people from all over the world post questions, problems and solutions regarding their cars. If I have a problem with my car, I can guarantee that one or more of the thousands of MG owners who visit this forum will likely have encountered it and will know the answer. Many users (obviously with a lot of time on their hands) have even created pictorial step-by-step instructions to help people with varying mechanical skills repair just about any problem with this model car.

Anyway, I'd communicated with this particular guy before via posts in the forum and knew he lived locally. Just recently, I was pleasantly surprised when he turned up out of the blue to say hello and to ask my advice about a key fob that no longer operated the alarm in his car.

Like many of us with pre-owned (read secondhand) cars, he had just one fob and key; two originally came with the car when it was new but for some reason, one had gone missing somewhere along the line. Getting another fob is no problem though; wreckers have boxes of them and copying the key is as simple as a trip to a local shopping mall. The problem is that each fob is tied electronically to the car's ECU (computer) and without the right one, the car cannot be started.

RECENTLY A BLOKE DROPPED INTO THE WORKSHOP

Items Covered This Month

- Resurrecting a faulty key fob
- XP: upgrade or not?
- The reversing spotlight that wouldn't switch off
- Faulty solar-power inverter
- Adding years to laser printers

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In this case, the key fob that came with the car had stopped working and even though he could open the doors with the key, the alarm was still armed and the engine immobilised. So without a working fob, he wasn't going anywhere. Interestingly, there is a sequence of key turns in the driver's door lock that turns off the alarm but nobody but the original owner ever seems to know it and guessing is out of the question.

Obviously, we needed to get his existing fob working and to be honest, I wasn't at all confident that we would be able to do so.

Opening the fob was easy; a spudger (a specially-made tool that's used for prodding, poking, prying and opening cases) made short work of separating the two halves of the case. And as soon as I opened it, I could see that something wasn't quite right. For a start, the battery was floating about the case in its holder and though I'm

no fob expert, I'm reasonably certain it should be connected to the PCB!

The next thing I noticed was that the inside of the fob was coated in some kind of greasy substance and while this could have been a silicone-based goop that had been used to prevent corrosion, I wasn't at all convinced. The PCB was also dotted with what appeared to be a greenish mould in several places underneath the goop. Another possibility was that these green spots were simply corrosion, due to a leaking battery.

Either way, I needed to clean the PCB and a sponge bath with a paint-brush and isopropyl alcohol soon had it looking new again.

Another problem became apparent as I cleaned the gel away; one of the two surface-mounted microswitches came away and disappeared into the workshop carpet. Like most workshops, my carpet hasn't seen a vacuum cleaner for a while so finding the tiny switch could be tricky. There's a way around that problem though – in situations like this, I use a decent-sized rare-earth magnet in a zip-lock bag and simply drag it over the carpet in a grid search pattern in the hope that the thing I'm looking for ends up stuck to the outside of the bag.

Sure enough, after a few passes my switch was there and once cleaned up I could see it had taken a small amount of PCB copper track with it. This seems to be a common problem with surface-mounted components that let go; they always seem to take the pads and some of the track as well.

Fortunately, this device wasn't too miniaturised and with my desk-lamp magnifier I could see what went where. My usual strategy with this type of repair is to use fine strands of hook-up wire formed into the shape of the missing track and then soldered into place. This is easy enough to do if there's sufficient room and while it's not an ideal solution for some repairs, in this case it worked quite well.

Once the new track was in place, I soldered the switch back in and re-soldered the battery connector which had simply broken away from its mounts. A new battery was then installed and after testing the switch for continuity, I applied a thin coating of 5-minute epoxy resin to keep everything in-place.

It didn't look great but it was secure and the case hid the repair. Best of all, when the client took it home, he found that he could disarm the alarm and drive the car so job done!

No support for Windows XP

If you have a desktop or laptop computer, chances are it runs a version of Microsoft's Windows operating system. And of those machines running Windows, it's estimated that around 30% are still running XP, which has turned out to be the most popular version of Windows ever made.

This was both a boon and a headache for Microsoft – a boon because it made a lot money for the company and a headache because so many satisfied customers equates to slow uptake and sales of later (and supposedly better) versions of Windows. Many XP users reasoned that if their current computer did everything they wanted it to do, then why bother upgrading?

How does that old adage go: if it ain't broke, don't fix it?

In the old days, whenever Microsoft launched a new version of Windows, people queued up outside stores overnight to be among the first get their hands on it. It was in some ways a pointless exercise because it was also often necessary for them to upgrade their hardware in order to satisfactorily run the new version.

...LIKE MOST WORKSHOPS, MY CARPET HASN'T SEEN A VACUUM CLEANER FOR A WHILE

When XP hit the shelves, many users upgraded directly from Windows 98, bypassing the buggy and underwhelming Windows ME in the process. But because XP was so much more demanding than 98, sales of hardware to provide the necessary hard disk space, memory and CPU power went through the roof, creating a mini-boom for everyone in the industry.

And XP kept on selling in vast numbers, although not all copies brought in revenue for Microsoft. It was estimated at one stage that pirated copies of XP were on at least one-quarter of the machines running the operating system, giving XP the dubious honour of being the most pirated software title on the planet at that time.

Indeed, during an overseas holiday, I recall being offered a copy for just $2.00 at a market stall in Bosnia Herzegovina. I passed on it but it's just

The reversing spot light that wouldn't switch off

P. E. of Heatcote, Victoria encountered a rather puzzling problem with the reversing lights in his Nissan Patrol. Here's how he solved it . . .

Some time ago, I installed a reversing spotlight on my Nissan Patrol. In the interests of safety, this light was wired so that it can only be operated when the car is in reverse and when I turn it on via a switch – or so I thought.

It all worked well after installation but recently a friend informed me that the light was on all the time, even when the vehicle wasn't in reverse. What's more, the original reversing lights weren't working at all.

That had me rather puzzled. First the easy stuff – I checked the fuses and lamps but they were all OK. So maybe the relay that activates the spotlight was jammed on? That tested OK too and it was beginning to look like a faulty reversing switch.

I'm lucky enough to have a platform onto which I can drive the car so that I can work under it with safety and ease. Once the car was on this platform, I spent about 40 minutes undoing the wiring loom plug and socket to the reversing switch (they are very awkward to get to) only to find that I still couldn't remove it.

It was covered in gunk so I cleaned the side of the gearbox with high pressure water and determined that the switch was a 19mm 'nut', shaped rather like a spark plug, with two white wires coming out of it. Unfortunately though, it wasn't possible to directly use a socket to remove it because it wouldn't fit over the loom plug on the other end of the wires.

Eventually, I gave in and cut the wires off close to the switch. This allowed me to place a long 19mm socket over the switch and go for it. After extending the handle with a pipe, it finally 'cracked' the seal and the reversing switch then screwed out easily.

Once I had the switch out, I could bench test it – just push in the plunger and the two contacts should close. This showed that it was intermittent, so I was on the right track.

These switches aren't meant to be disassembled but that's never stopped me before. In fact, I'd repaired a similar brake-light switch in the past. In this case, I began by placing the reversing switch in a lathe and machining off the folded metal that holds the plastic body to the 'nut'. It then came apart quite easily.

The inside was full of very thick oil and it appeared that the brass contacts had worn. There wasn't any way of bending the contacts to work again so I reasoned that if the body of the switch went into the gearbox another 2mm, the plunger would make better contact. As a result, I machined 2mm off the body using a lathe and reassembled the switch after cleaning it, sealing the plastic and metal together with 5-minute epoxy adhesive.

That done, I then screwed the switch back into the gearbox, using a small amount of sealant as Nissan had done, and reconnected the leads. A quick test revealed that I now had reversing lights again but the spotlight was still on all the time.

It didn't take me long to track down this fault. When I first wired the spotlight in, I decided that it was easier to turn it on or off by switching its earth lead rather than the positive lead. However, I forgot that the mounting bolt was in the earth path to the light.

When I originally installed it, this bolt was insulated from the chassis and all was well. However, with ensuing vibration as the vehicle was driven, the mounting insulation had worn away and the mounting bolt was able to contact the chassis, thus bypassing the switch and turning the spotlight on.

Insulating the mount fixed the problem. So I actually had two faults and both were intermittent.

one example of how prevalent piracy had become, despite the sophisticated anti-piracy measures implemented by Microsoft (but ultimately circumvented) in an effort to minimise the damage to their bottom line.

Following on from XP, Microsoft released a new, much-anticipated version of Windows called Vista. However, Vista proved to be so unpopular (deserved or not) that many new computer buyers took advantage of a "downgrade to XP" option that vendors scrambled to introduce at the time in an effort to shore up sagging sales. Vista tarnished Microsoft's image and while Windows 7 eventually helped the company claw back some of that lost market share, XP still dominated the operating system charts.

And therein lies the problem; many XP users don't seem to fully grasp that it's no longer safe to use now that Microsoft has ended support for XP (as of April 8th). Some even see the upgrade campaign as a marketing putsch with them as the patsies because upgrading to Windows 7 or Windows 8 will be an expensive exercise as new hardware will invariably be required.

But Microsoft is putting increasing pressure on people to do just that, rolling out end-of-life messages via Windows' automatic update system to encourage users into upgrading. It's a strategy that's worked with many XP users but has merely confused and/or annoyed others. Some of my customers have even told me that they feel resentful at having to shell out and upgrade just because someone says they should.

Unfortunately, that's the price of progress; the computer industry never stands still. Indeed, it's been fashionable for some time for "techno-gurus" to put the boot into XP as being old-hat and obsolete and to portray XP users being old-fashioned and out-of-touch.

So what does Microsoft's end of support decision really mean? It means that no further updates will be issued for the operating system, no matter how serious or critical the reason for an update may be. This is why your XP system will be more vulnerable to exploits or threats, especially those discovered after April 8th.

It also means that if you call Microsoft for assistance and say you are run-

~GIVING XP THE DUBIOUS HONOUR OF BEING THE MOST PIRATED SOFTWARE TITLE ON THE PLANET...

ning Windows XP, the support person will tell you that this operating system is no longer supported.

If you decide to buy new hardware for your computer, you will increasingly find that Windows XP is missing from the minimum system requirements, meaning device drivers for XP will not be included. As a result, there's no guarantee the new hardware will work with XP. I've already struck this problem in my own workshop. Recently, I bought a new motherboard for a client's system and discovered that no XP drivers were included on the supplied disk and nor were any available for download from the manufacturer's website.

This graphically illustrates what can happen when using an unsupported operating system. XP will still boot and run quite happily on existing machines but it is inevitable that lack of support from third-party hardware and software vendors will become increasingly prevalent.

At the end of the day, the best advice is to upgrade, particularly if you want to connect to online services. Windows XP is no longer secure and in any case, a machine that's running Windows XP is generally well past its "use-by-date".

Keeping on with XP

In spite of the advice to upgrade, some users will have to keep using XP by sheer necessity. This could be, for example, because they are running a type of bespoke software that controls C&C machinery or an inventory system that will not run on anything later than Windows XP and is simply too expensive to replace.

I have several clients still running Windows 98 for similar reasons and while it isn't practical for the likes of on-line banking, it still does the job and does it surprisingly well (just don't connect it to the internet).

One way around this problem is to use a technology called "virtual machine", which allows you to run an older version of Windows inside the framework of an up-to-date operating system. Once installed, it's as simple as clicking an icon on the desktop and a window opens with the older version of Windows (95, 98, XP or even DOS) booting inside it – just as it would if it was installed directly onto the hardware platform.

The advantage of a virtual machine is that you can use the latest printers, scanners, plotters, graphics tablets and other sophisticated hardware not even dreamt of when older operating systems were being developed. The host operating system takes care of all that while the virtual machine runs the older version of Windows and whatever old software you want to install on it. Brilliant!

Technology won't stop

At the end of the day, the technology juggernaut will not stop; you can keep using XP for as long as you want and as long as secure on-line resources such as banks and payment gateways will let you – if you're prepared to take the security risk, that is. However, be aware that while a few die-hard fans may get together to provide unofficial patches and support (as has happened with other abandoned versions of Windows), you'll be pretty much on your own. Your mileage will vary considerably depending on the software you currently run and how long you'll be able to continue using it before it too is flattened by progress.

At the time of writing, I hear that some banks and other organisations are contemplating blocking XP users from using their online services. Of course, implementing such measures while so many are still using XP is a difficult choice to make.

Finally, if you are running Windows XP and would like to know whether your hardware is up to running a later version of Windows (and what programs would be affected if you did decide to upgrade), you can download a nifty program from Microsoft that

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will give you this information. You'll find the Windows 7 Upgrade Advisor at http://www.microsoft.com/en-us/download/details.aspx?id=20

Similarly, the Windows 8 Upgrade Assistant is at http://go.microsoft.com/fwlink/p/?LinkId=321548

Faulty solar-power inverter

A. W. of Adelaide SA recently tackled a faulty inverter that was part of a solar power installation. Here's his story . . .

Late last year, my father's grid-connect solar panel inverter failed. And as Murphy would have it, it failed just as the summer sun was about to provide the peak annual output.

The only signs of life from the inverter were the power LED and a 'relay failure' message on the LCD. Turning it off and then back on again at the isolation switch had no effect.

At the time, the inverter was only about 2.5 years old and was still within warranty. Unfortunately, this warranty proved to be worthless because both the solar panel installer (who also supplied the inverter) and the importer had since gone bust, so there was no point pursuing a warranty claim.

As a result, my father contacted a "solar experienced" sparky who promptly visited and dismissed the inverter as being a cheap brand that was unrepairable. He didn't even open the unit up and his only action was to turn off the isolation switch. His quote for a replacement inverter was $2200, including installation (30 minutes work at most).

Being the family's electronic "nut", I was asked to have a look at it. Initially, I left it mounted on the wall (but with the isolation switch definitely off) and carefully removed the front cover. I then took a good look inside but there were no obvious signs of distress – no blown FETs, no bulging capacitors and no signs of overheating. In fact, the interior looked to be factory fresh, without so much as a layer of dust.

I could see two large relays near the top of the inverter and this was a logical area to focus on given the "relay failure" message on the LCD. However, I had my doubts as to the accuracy of this "relay failure" message. Unless there were auxiliary contacts on the relays, the circuit couldn't possibly monitor their operation directly and it was possible that a fault elsewhere could give the same message. Some manufacturers also seem to be reluctant to display messages such as "unknown fault", so it's possible that "relay failure" was simply a 'catch-all' fault indication.

By this stage, I wasn't feeling very hopeful, although opening the inverter did reveal one useful fact – the mains lead was connected via a plug and socket arrangement. Thus enlightened, I used a small flat screwdriver to release the latching mechanism, after which the mains cable was easily unplugged. The solar panel connectors swiftly followed.

It was then simply a matter of lifting the somewhat weighty inverter off its wall bracket, all while somewhat precariously balanced atop a ladder over a large pot plant! I subsequently attempted to track down a local service outlet for solar panel inverters but drew a complete blank. I was literally on my own.

A few days, later I dropped it (gently) on my service bench and made a closer visual inspection. This revealed two ever so slightly bulgy capacitors. Both were 1000µF and were (coincidentally) near the two large relays.

I wasn't immediately pleased with the thought of dodgy electrolytic capacitors as there were lots of them, ranging from many small ones up to several large high-voltage units. A couple of dud capacitors could easily be the tip of the iceberg and replacing all the electrolytics in this inverter wasn't my idea of fun.

Fortunately, a closer look revealed that the two faulty capacitors were a different colour to all the others. This indicated that they were a different (possibly inferior) brand and thus did not portend a capacitor "plague of doom". So there was a chance that they were the only fault in the unit and nothing else was likely to fail (at least in the near future).

In the end, I decided that it was worth taking a punt and replacing them but first I had to remove the board from the case. This task initially looked to be quite formidable as there were three large off-board inductors connected via thick flying leads plus several flat-pack semiconductors mounted on heatsinks that protruded through cut-outs in the board. And that's not taking into account the numerous screws that secured the board inside the case.

Fortunately, the flying inductor leads were terminated in female spade connectors and these leads were all labelled. A pair of pliers was required to detach a couple of the more obstinate connectors but a few minutes work soon had them all disconnected. The screws securing the semiconductors to the heatsinks were then removed and each device prised free of the heat transfer 'goop'.

That done, the mounting screws holding the board in place were all removed and it then took only a few minutes to lift the board clear and replace the two bulging capacitors with new 105°C 1000µF units (the originals were also rated at 105°C). I then checked the original capacitors on my capacitance meter and both were well down, measuring only about 300µF instead of 1000µF.

After reassembling the inverter, I took it back to my parents' home, reinstalled it on its wall bracket and reattached the solar panel and mains connectors. With some trepidation, I then switched on the isolator and waited for what seemed like an eternity for the inverter to go through its self-check routine.

To my surprise, it all worked and it was still working well several weeks later. So $3.00 worth of parts avoided a $2200 bill for a replacement. Jokingly, I offered to split the difference with my father but he quickly declined!

This episode did raise a couple of

Servicing Stories Wanted

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Adding Years To Laser Printers

Nothing is more annoying than a laser printer that continually feeds through extra sheets of blank paper or picks up extra sheets and jams. The fix, according to N. K. of Kedron, Qld, is often quite simple . . .

I have successfully worked on several old laser printers that had given sterling service but had then developed a paper handling problem. In each case, the solution was simple and cost nothing but some insulation tape and some time.

The paper feed problem occurs when they start pulling in extra pages, one at a time. I have seen it on several HP Laserjet printers but it may affect other brands too.

The problem presents in one of two different ways. In some cases, the wanted pages print perfectly but then additional blank sheets feed through until the paper tray is emptied or the user intervenes and stops it. Alternatively, in some cases, the printer stops before the end of the first page and displays a "Paper Jam" error.

This problem is caused when the rubber roller touching the paper stack that feeds in the blank paper continues to rotate and doesn't stop. Normally, this roller should do one revolution to get the page to the next set of rollers. Once the paper detector "sees" that the page has started, the initial roller is then supposed to stop until another page is needed.

However, if it continues to turn, it has no effect until the current page has passed. It then immediately picks up the next sheet and overlaps it with the page already printing. This makes the page appear to the detectors as one single super-long sheet.

Most models expect the paper detector to register the end of a page after a certain time and if not, the printer assumes there has been a jam. On these models, the user first needs to pull out the almost-finished sheet, which will have stalled in the hot fuser rollers, and then pull back the second sheet to clear the jam.

By contrast, other models do not look for the end of a page and so they just keep on feeding sheets.

In these laser printers, the page pick-up roller is driven by a friction clutch, and roller's shaft has a wheel with a tooth or indent. A solenoid that looks like a large relay is mounted next to this wheel and the moving end of the armature is bent out to create a pawl (ie, a pivoted curved bar) that's normally engaged with the tooth/teeth/indent on the wheel. This normally prevents the shaft from turning, causing the clutch to slip.

Conversely, when a page is needed, the solenoid operates (usually with a click) and the pawl is pulled away from the wheel, allowing the shaft to turn.

In all printers with this problem, the solenoid's armature either sticks or fails to release for some time after the solenoid has been de-energised. As a result, the pawl remains clear of the wheel and the clutch keeps turning the roller which picks up extra sheets.

After opening the printer, which can be a puzzle on some models, I first locate the solenoid. In printers with this problem, if you manually operate the solenoid (with the power disconnected, of course) by momentarily pushing it with a screwdriver, it sticks. This immediately indicates a solenoid fault and, at the same time, removes suspicion from the control circuitry.

When I first came across this problem, I thought that it was residual magnetism in the pole that was making the armature stick. However, it turned out to be a little adhesive foam pad between the armature and the pole. In each case, this pad, which is apparently included to muffle the click when the solenoid operates, had deteriorated into a sticky goo.

My solution is to first remove some of the goo by pulling through strips of paper while pressing the gap closed. After that, I stick two pieces of insulation tape in place, one to the pole and one on the armature. These tapes, together with the remnant goo, serve the purpose of the original pad and the printer will then last another few years.

questions in my mind though. There must be a lot of inverters (of varying quality) out there that have now either failed or will do so in the next few years. Given the high replacement cost of an inverter, this would seem a lucrative opportunity for some enterprising repair outfit. Or is it too hard to source parts or schematics, or are there are just too many different designs to keep up with?

Or perhaps too many inverter failures are due to the elements – a water damaged inverter is almost certainly going to be a write-off! Certainly, my father's inverter didn't exactly fill me with confidence when it came to weatherproofing (or rather, lack of it). The front cover simply slipped over the back portion of the case, with an overlap of perhaps 30mm between the two pieces to keep water out. There were no rubber gaskets.

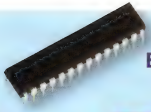
However, because the overlap on the top of the case is in the horizontal plane, it's inevitably going to let water in if exposed directly to the elements. It's not a problem in my father's case though, because the inverter is mounted in a sheltered location where it will never be exposed to rain or direct sunlight.

Most inverters will not be so fortunate. The first supplier I obtained a quote from when I was considering a similar system wanted to put the inverter right next to the fusebox, where it would be fully exposed to all the elements. When I asked if they could mount it under my carport, they hesitated for quite some time before eventually agreeing that it was possible.

They also wanted to mount the panels on the only sloped part of my roof, which faces west, not north, claiming that the reduction in output "wouldn't be much". They didn't get my business.

The next supplier I approached was far more knowledgeable and immediately suggested mounting the inverter under the carport and installing an angled frame to mount the panels on, to orientate them correctly on my mostly flat roof. Unfortunately, due to sloth on my part, they didn't get my business either (and nor did anyone else). Perhaps it was for the best, as they've since folded also. SC

Using the Micromite, Pt.2



By GEOFF GRAHAM

Interfacing & controlling external devices

Now that you know how the Micromite works, we'll dive right in with some useful programming tips and show how to control external devices. In particular, we'll show how to use it for infrared (IR) remote control, to measure temperature, control a servo, interface to an LCD and keypad and much more.

LAST MONTH, we introduced the Micromite – a low-cost 28-pin microcontroller running a Microsoft-compatible BASIC interpreter called MMBasic. MMBasic is easy to use and gives your Micromite-based project the ability to measure, react to and control all sorts of external parameters and devices.

In particular, MMBasic includes a number of powerful commands that allow you to measure voltages, respond to an infrared remote control, display data on an LCD, measure distance and much more. This month, we're going to show you how to use these commands and more.

To make it easier for a program to interact with external devices, the Micromite includes drivers for a number of common peripheral devices. In some cases, it's possible to achieve the same outcome by manipulating the Micromite's I/O pins in BASIC but these drivers have the convenience of packaging the requirement into one or two easy-to-use commands.

If you want to go beyond these commands and access various specialised features of an external device, you can always develop your own driver to directly drive the I/O pins.

IR remote control decoder

Adding an infrared remote control to your project requires very little effort thanks to the IR command in MMBasic. When enabled, this function runs in the background and interrupts the running program whenever a key is pressed on the IR remote. It will work with any Sony-compatible remote, including controls using 15-bit or 20-bit messages (most cheap universal remote controls can generate Sony commands).

To detect the IR signal, you need an IR receiver connected to the Micromite's IR pin (pin 16) – see Fig.1. The receiver will sense the IR light, demodulate the signal and present it as a TTL voltage level signal to this pin. Set-up of the I/O pin (pin 16) is automatically carried out by the IR command.

Sony-compatible remote controls use a 40kHz modulation frequency but receivers for that frequency can be hard to find. Generally, 38kHz receivers will work fine but maximum sensitivity will be achieved with a 40kHz device such as the Vishay TSOP4840. Examples of 38kHz receivers that work include the Vishay TSOP4838, Jaycar ZD1952 and Altronics Z1611A.

To set-up the decoder you use the command

```
IR dev, key, interrupt
```

where **dev** is a variable that will be updated with the device code and **key** is the variable to be updated with the key code. **Interrupt** is the interrupt label to call when a new key press has been detected (interrupts are described in detail later in this article).

The IR decoding is done in the background and the program will continue after this command without interruption.

The following example shows how to use the IR decoder:

```
IR DevCode, KeyCode, IR_Int  ' start the IR decoder
DO
  < body of the program >
LOOP

IR_Int:                      ' a key press has been detected
  PRINT "Received device = " DevCode " key = " KeyCode
  IRETURN
```

Sony remote controls can address many different devices (DVDs, TVs etc) so the program would normally examine the device code first to determine if the signal was intended for the program. If it was, it then takes action based on the key pressed. There are many different devices and key codes so the best method of determining what codes your

The Vishay TSOP4838 is a typical infrared receiver that will work with the Micromite. By using this and any Sony compatible remote control, you can add infrared remote control to your Micromite based project.

remote generates is to use the above program.

IR remote control transmitter

The IR SEND command allows you to transmit a 12-bit Sony-compatible infrared remote control signal. This could be used to control a Sony product that uses 12-bit codes or communicate with another Micromite.

Fig.2 shows what's required. A transistor (Q1) is used to drive the infrared LED because the output of the Micromite is limited to about 10mA, which would not provide a very bright infrared signal. This circuit provides about 50mA to the LED which is much better.

To send a signal, you use the command

IR SEND pin, dev, key

where **pin** is the I/O pin used, **dev** is the device code to send and **key** is the key code. Any I/O pin on the Micromite can be used and you do not have to set it up beforehand (the IR SEND command will automatically do that).

Note that the modulation frequency used is 38kHz and this matches the common IR receivers (described above) for maximum sensitivity when communicating between two Micromites.

Measuring temperature

The DS18B20() function in MMBasic will get the temperature from a DS18B20 temperature sensor. This device can be purchased on eBay for about $5 in a variety of packages, including a waterproof probe version.

The DS18B20 can be powered separately from a 3-5V supply (see data sheet) or it can operate on "parasite power" from the Micromite's data line as shown in Fig.3. Multiple sensors can be used but note that a separate I/O pin and pull-up resistor is required is required for each one.

To get the current temperature, you just use the DS18B20() function in an expression. For example:

PRINT "Temperature: " DS18B20(pin)

where pin is the I/O pin to which the sensor is connected. You do not have to configure the I/O pin; that's handled by MMBasic.

The returned value is in °C with a resolution of 0.25°C and is accurate to ±0.5°C.

The time required for the overall measurement is 200ms and the running program will pause for this period while the measurement is being made. This also means that interrupts will be disabled for this period. If you don't want this to happen, you can separately trigger the measurement then return later to retrieve the reading. That's done with the DS18B20 START command as described in the Micromite User Manual (available for download from the SILICON CHIP website).

Real time clock interface

Using the RTC GETTIME command, it's easy to get the current time from a PCF8563 real time clock. This inte-

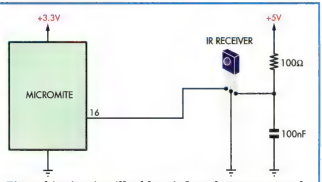


Fig.1: this circuit will add an infrared remote control decoder to your Micromite project. The receiver can be a Vishay TSOP4838, Jaycar ZD1952 or Altronics Z1611A and the remote control can be any Sony compatible infrared remote control, including controls using 15 or 20-bit messages.

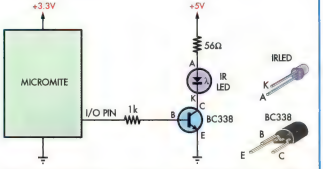


Fig.2: this is all you need to generate Sony compatible 12-bit remote control signals. This could be used to control a Sony product or communicate with another Micromite.

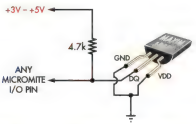
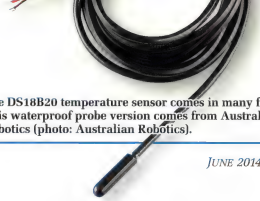


Fig.3: measuring temperature is easy using the DS-18B20 temperature sensor. It can operate on parasitic power from the Micromite with V_{DD} grounded as shown here or it can be powered separately by a 3-5V supply directly connected to the V_{DD} terminal.



The DS18B20 temperature sensor comes in many forms. This waterproof probe version comes from Australian Robotics (photo: Australian Robotics).

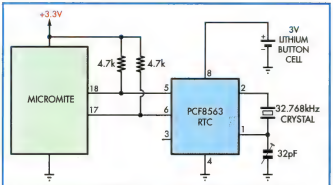
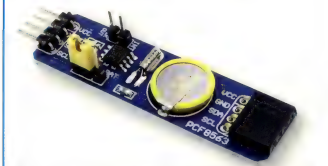


Fig.4: adding a PCF8563 real time clock means that your Micromite-based project will always know the correct time. Because the PCF8563 draws very little current it can be permanently connected to a 3V cell as shown here. The 32pF adjustable capacitor is used to trim the crystal frequency for very accurate timekeeping but can be left out completely.



This is a typical pre-assembled real time clock module using the PCF8563 chip. Photo by www.wvshare.com

grated circuit is popular and cheap and will keep accurate time to about ±50ppm, even with the power removed (it's battery backed).

The PCF8563 can be purchased for around $5 on eBay and complete modules using the PCF8563 along with a battery can be found for as little as $10.

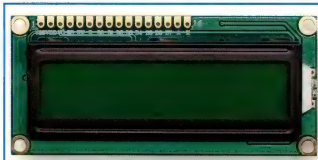
This is an I²C device and it should be connected to the I²C I/O pins of the Micromite. Also, because the PCF8563 draws very little current (even when communicating via I²C), it can be permanently connected to the lithium cell (typical cell life is 15 years).

Fig.4 shows the circuit details. The 32pF adjustable capacitor is used to trim the crystal frequency for very accurate timekeeping. However, that can be tedious as it will involve checking the time for drift over several days or even weeks. If you don't want to do that, you can substitute a 10pF capacitor or leave it out completely and the timekeeping will still be quite good.

Before you can use the PCF8563, its time must first be set. That's done with the RTC SETTIME command which uses the format *RTC SETTIME year, month, day, hour, minute, second*. Note that the year is just the last two digits (ie, 14 for 2014) and the hour is in 24-hour format. For example, the following will set the PCF8563 to 4PM on the 10th November, 2014:

```
RTC SETTIME 14, 11, 10, 16, 0, 0
```

To retrieve the time, you use the RTC GETTIME command which will read the time from the PCF8563 and set the clock inside the Micromite. Normally, this command will be placed at the beginning of the program so that the time is set at power-up.



The LCD command will work with 1, 2 or 4-line LCD modules that use the KS0066, HD44780 or SPLC780 controller chip. This is a typical example supplied by NexusCyber Electronics.

Left to its own devices, the clock in the Micromite can drift by as much as two or three seconds in an hour. If an accurate time is required over a long period, the PCF8563 can be polled at regular intervals using the SETTICK command, eg:

```
RTC GETTIME                          ' set the time at startup
SETTICK 12 * 3600000, SetTime, 4     ' interrupt every 12 hours
< normal program >

SetTime:                             ' interrupt called every 12 hours
  RTC GETTIME                        ' reset the time
  IRETURN
```

LCD readout

The LCD command will display text on a standard LCD module with just a few lines of BASIC. It will work with LCD modules that use the KS0066, HD44780 or SPLC780 controller chip and have 1, 2 or 4-line displays. Suitable modules include Altronics Z7001, Jaycar QP5512 and Futurlec LCD16X2. eBay is another good source and prices typically range from $10 to $50.

A keypad is a low-tech method of entering data into a Micromite-based system and it's easy to connect a 4x3 keypad like this to your project. Photo by Vetco.

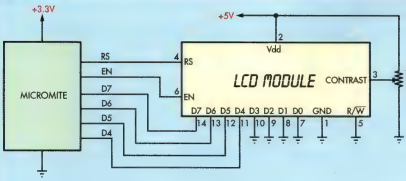


Fig.5: adding a 1, 2 or 4-line LCD to a Micromite is easy. Any I/O pins on the Micromite can be used and you do not have to set them up beforehand – the LCD command automatically does that for you.

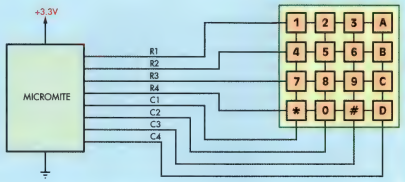


Fig.6: a keypad is a simple & convenient method of entering data into a Micromite based system. The Micromite supports either a 4x3 or a 4x4 keypad and the monitoring and decoding of key presses is done in the background while your program keeps running in the foreground.

To set-up the display, you use the LCD INIT command as follows:

```
LCD INIT d4, d5, d6, d7, rs, en
```

where **d4**, **d5**, **d6** & **d7** are the I/O pins that connect to inputs D4, D5, D6 & D7 on the LCD module (inputs D0-D3 and R/W on the module should be connected to ground); **rs** is the pin connected to the register select input on the module (sometimes called CMD or DAT); and **en** is the pin connected to the enable or chip select input on the module.

Any I/O pins on the Micromite can be used and you do not have to set them up beforehand (the LCD command automatically does that for you). Fig.5 shows a typical set up.

To display characters on the module, you use the LCD command, as follows:

```
LCD line, pos, data$
```

Where **line** is the line on the display (1-4), **pos** is the position on the line where the data is to be written (the first position on the line is 1) and **data$** is a string containing the data to write to the LCD display. The characters in data$ will overwrite whatever was on that section of the LCD line.

The following shows a typical usage:

```
LCD INIT 2, 3, 4, 5, 23, 24
LCD 1, 2, "Temperature"
LCD 2, 6, STR$(DS18B20(15))
```

Note that this example also uses the DS18B20 function to get the temperature (described above) and that the sensor is connected to pin 15.

Keypad interface

A keypad provides a simple method of entering data into a Micromite-based system. The Micromite supports either a 4x3 or a 4x4 keypad and key presses are monitored and decoded in the background.

An example of a 4x3 keypad is the Altronics S5381, while the Altronics S5383 is a 4x4 keypad.

When a key press is detected, an interrupt is issued and during this interrupt routine, the program can take whatever action is required (interrupts are described later).

To enable the keypad feature you use the command:

```
KEYPAD var, int, r1, r2, r3, r4, c1, c2, c3, c4
```

where **var** is a variable that will be updated with the key code; **int** is the label of the interrupt to call when a new key press has been detected; **r1**, **r2**, **r3** & **r4** are the pin numbers used for the four row connections to the keypad (see Fig.6); and **c1**, **c2**, **c3** & **c4** are the column connections.

Note that **c4** is used only with 4x4 keypads and should be omitted if you are using a 4x3 keypad.

Fig.6 shows the circuit. Any I/O pins on the Micromite can be used and you do not have to set them up beforehand; the KEYPAD command will automatically do that for you.

The detection and decoding of key presses is done in the background and the program will continue after this command without interruption. When a key press is detected, the value of the variable **var** will be set to the number representing the key (these are listed in the Micromite User Manual). Then the interrupt subroutine will be called, eg:

```
Keypad KeyCode, KP_Int, 1, 2, 3, 4, 8, 9, 10   ' 4x3 keyboard
DO
  < body of the program >
LOOP

KP_Int:                                  ' a key press has been detected
  PRINT "Key press = " KeyCode
  IRETURN
```

Table 1: CPU Speed vs Current	
CPU Speed	**Current Draw**
48MHz	25mA
40MHz (default)	21mA
30MHz	16mA
20MHz	12mA
10MHz	7mA
5MHz	4mA

Controlling a servo

A servo is basically a motor with integrated gears and a control system that allows its shaft position to be precisely controlled. The Micromite can simultaneously control up to five servos.

Standard servos allow the shaft to be positioned at various angles, usually between -90° and +90°. Continuous rotation servos also allow the shaft rotation to be set to various speeds.

The position of the servo is controlled by a signal pulse which is repeated every 20ms. Generally, a pulse width of 0.8ms will position the rotor at -90°, a pulse width of 2.2ms will position it at +90° and a pulse width of 1.5ms will centre the rotor. However, note that these numbers can vary between manufacturers.

Most servos require a high current 5V power source and have two power leads, red for +V and black for ground. The third wire is the control signal which should be connected to a Micromite SERVO I/O pin. Depending on their size, servos can be quite powerful but the control signal used remains the same.

The Micromite has two servo controllers, the first capable of controlling up to three servos and the second two servos. To drive a servo, you use this command for the servos connected to controller 1:

```
SERVO 1, 1A, 1B, 1C
```

Similarly, this is the command for for the servos connected to controller 2:

```
SERVO 2, 2A, 2B
```

The labels **1A**, **1B**, **1C**, **2A** etc are the desired pulse widths in milliseconds for each output of the channel. The output pins are designated as **PWM 1A**, **PWM 1B**, **PWM 2A** etc (the PWM and SERVO commands are closely related and use the same I/O pins). These I/O pin functions were shown in Fig.1 in last month's article which introduced the Micromite.

If you want to control less than the maximum number of servos, you can simply leave the unused output off the list and use that pin as a general purpose I/O.

The pulse width can be specified with a high resolution (about 0.005ms). For example, the following will position the rotor of the servo connected to channel 1A to a position near its centre:

```
SERVO 1, 1.525
```

Following the SERVO command, the Micromite will continue to generate a stream of pulses with this duty cycle in the background until another servo command is given or the STOP option is used (which will terminate the output).

As another example, the following will swing two servos connected to outputs PWM 1A and PWM 1B back and forth alternatively every five seconds:

```
DO
  SERVO 1, 0.8, 2.2
  PAUSE 5000
  SERVO 1, 2.2, 0.8
  PAUSE 5000
LOOP
```

Measuring distance

By using an HC-SR04 ultrasonic sensor and the DISTANCE() function, you can measure the distance to a target. The HC-SR04 device can be found on eBay for about $5 and it will measure distances from about 30mm out to 3m. It works by transmitting an ultrasonic sound pulse and the Micromite then measures the time it takes for the echo to be returned.

The DISTANCE function is used as follows:

```
d = DISTANCE(trig, echo)
```

where **trig** is the I/O pin connected to the sensor's trigger input and **echo** is the pin connected to the sensor's echo output. Note that the HC-SR04 ultrasonic sensor is a 5V device and so the echo pin should be a 5V-capable pin.

As with previous functions, the Micromite's I/O pins are automatically configured by the distance function. The value returned is the distance in centimetres to the target or -1 if no target is detected.

If you want to use multiple sensors, they can share the same **trig** output from the Micromite but you must use different I/O pins for the echo input. You can also use 3-pin devices and in that case only one pin number need be specified.

Saved variables

Because the Micromite does not have a normal storage system (such as an SD card) it needs a facility to save information when the power is switched off. That's done with the VAR SAVE command which will take a number of variables on its command line and will save their values in non-volatile flash memory. The space reserved for saved variables is 1.5KB.

These variables can be restored later with the VAR RESTORE command which will add the saved variables to the variable table of the running program. Normally, this command is placed near the start of a program so that the variables are ready for use when the Micromite is powered up.

This facility is intended for saving data such as calibration data, user selected options and other items which change infrequently. It should not be used for frequent saves as this could wear out the flash memory.

The flash in the PIC32MX150/250 series of chips has a high endurance of over 20,000 writes and erases. With normal use, this will never be reached but it could be exceeded by a program that repeatedly saves variables. For example, a program that saved a set of variables once a second would wear out the flash memory in six hours, while a program that saved the same data once a day would run

for over 50 years and still not wear out the flash memory.

CPU speed control

MMBasic can control the Micromite's clock speed via the CPU command. At start-up, the chip will run at 40MHz but the speed can be changed under program control from 5MHz to 48MHz. The current drawn by the chip is proportional to the clock speed so this command can be used to balance performance against current consumption.

Table 1 (measured on a PIC32MX150F128B-I/SP) illustrates this.

When the clock speed is changed all the serial ports (including the console) will be unaffected although there may be a small glitch during any change. The internal clocks and timers will also be unaffected. By contrast, the PWM, SPI and I^2C functions will have their speeds changed proportionally so if this is not desired, they should be shut down before the change and restarted again afterwards.

CPU sleep

For battery-powered operation, it's handy to be able to power the chip down completely and start it up again on some event. With the Micromite, you can use the CPU SLEEP command which will put the processor to sleep with a current drain of about 80µA.

While it's asleep, the chip monitors the WAKEUP pin which is automatically set up as a digital input by the CPU SLEEP command. The CPU will then be woken up when the WAKEUP pin changes state (ie, goes from high to low or low to high). The program will then continue with the command following the CPU SLEEP command.

The wake-up signal could be a button press, an incoming signal or some other external interrupt.

The infrared remote control function uses the same I/O pin as the wake-up signal and it's possible to combine the two so that an incoming IR signal will wake the Micromite which will then decode that signal. In this way, you can have a Micromite running on battery power that will wake up on an IR signal, do something based on that signal, then go back to a low-power sleep mode.

The following is an example:

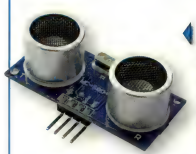
```
IR DevCode, KeyCode, IR_Int  ' start the IR decoder
DO
  CPU SLEEP                  ' now sleep until a signal
LOOP

IR_Int:                      ' a key press has been detected
  < do some work based on the key press >
  IRETURN                    ' return to sleep again
```

Watchdog timer

The main use for the Micromite is as an embedded controller. It can be programmed in MMBasic and when the program is debugged and ready for "prime time" the AUTORUN configuration setting can be turned on. The chip will then automatically run its program when power is applied and act as a custom integrated circuit performing some specific task. The end user need not know anything about what is running inside the chip.

However, it's possible that a fault in the program could cause MMBasic to generate an error and return to the command prompt. This would be of little use in an embedded situation as the Micromite would not have anything connected to the console.

The Micromite can control up to five servos like this unit. Photo courtesy Wikimedia Commons.



The HC-SR04 distance measuring sensor will enable your Micromite project to measure the distance to an object. It's useful for robotics, tank level monitoring and many other applications. Photo by Robotsoft Systems.

Another possibility is that the BASIC program could get itself stuck in an endless loop for some reason. In both cases, the visible effect would be the same . . . the program would stop running until the power was cycled.

To guard against this, the watchdog timer can be used. This is a timer in MMBasic that counts down to zero and when it reaches zero the processor is automatically rebooted (the same as when power was first applied), even if MMBasic was sitting at the command prompt.

In practice, the WATCHDOG command should be placed in strategic locations in the program so that it keeps resetting the timer and thus prevents the counter from reaching zero. Then, if a fault occurs, the program will stop running and the timer will not be reset. As a result, it will now count down zero and the program will be restarted (assuming the AUTORUN option has been set).

PIN security

Sometimes, it's important to keep the data and the program in an embedded controller secret. This can be done in the Micromite by using the OPTION PIN command. This command will set a PIN number (which is stored in flash memory) and whenever the Micromite returns to the console (for whatever reason) the user will be prompted to enter the PIN.

Without the correct PIN, the user cannot get to the command prompt. The only options are to enter the correct PIN or reboot the Micromite. However, if it's rebooted, the user will still need the correct PIN to access the command prompt. Because an intruder cannot reach the command prompt, they cannot list or copy a program, nor can they

change the program or change any aspect of MMBasic or the Micromite.

Once set, the PIN can only be removed by providing the correct PIN in the first place. If the number is lost, the only method of recovery is to reset MMBasic as described later (which will erase the program).

Note that there are complicated (and expensive) methods of accessing the data on the chip even if a PIN has been set (eg, by removing the plastic packaging and physically accessing the silicon die).

The serial console

Using the OPTION BAUDRATE command, the baud rate of the console can be changed to any speed up to 230,400bps. Changing the console baud rate to a higher speed makes the full screen editor much faster when it comes to redrawing the screen. So, if you have a reliable connection to the Micromite, it's worth changing the speed to at least 115,200bps.

When running as an embedded controller the serial console may no longer be required for programming. This means that it can then be used as a third serial port, with OPTION BAUDRATE used to set the required speed. If you do this, it might be worth using the OPTION BREAK command to disable the break key to prevent an unintended CTRL-C in the console receive data from halting the running program.

Once changed, the console baud rate will be permanently remembered unless another OPTION BAUDRATE command is used to change it. Note that when using this command it's possible to accidentally set the baud rate to an invalid speed. If that happens, the only way out is to reset MMBasic as described later.

Digital inputs

A digital input is the simplest type of input pin configuration. If the input voltage is higher than 2.5V, the logic level will be high (numeric value of 1), while anything below 0.65V will be low (numeric value of 0). The digital inputs all use Schmitt trigger logic, so anything in between these levels will retain the previous logic level.

In your BASIC program, you would set the input as a digital input and use the PIN() function to get its level. For example:

```
SETPIN 23, DIN
IF PIN(23) = 1 THEN PRINT "High"
```

The SETPIN command configures pin 9 as a digital input and the PIN() function will return the value of that pin (the number 1 if the pin is high). The IF command will then execute the command after the THEN statement if the input was high. If the input pin was low, the program would just continue with the next line.

Analog inputs

Pins marked as ANALOG can be configured to measure the voltage on the pin. The input range is from 0V to 3.3V and the PIN() function will return the voltage. For example:

```
> SETPIN 23, AIN
> PRINT PIN(23)
2.345
>
```

You will need a voltage divider if you want to measure voltages greater than 3.3V. For small voltages, you may need an amplifier to increase the input voltage to make an accurate measurement.

One small point here is that when the Micromite measures voltage, it uses pin 28 (analog power) as its reference and assumes that this pin is at exactly 3.3V. If you use a different supply voltage, you will need to scale the reading in your BASIC program to compensate. For example:

```
Volts = PIN(pin) / 3.3 * Vdd
```

where **Vdd** is the supply voltage.

Many devices generate an output voltage that represents a physical quantity. Examples include accelerometers, strain gauges, pressure sensors and humidity sensors. You can use this same technique to measure the voltage output from these sensors and scale the reading to a meaningful number.

Counting inputs

The pins marked as COUNT (ie, pins 15-18) can be configured as counting inputs to measure frequency or period, or to just count pulses on the input. For example, the following will print the frequency of the signal on pin 15:

```
> SETPIN 15, 3
> PRINT PIN(15)
110374
>
```

In this case, the frequency is 110.374kHz.

The frequency response ranges up to 200kHz maximum and the measurement is returned in Hz with a resolution of 1Hz. The value is updated once a second (ie, the gating period is 1s).

For accurate measurement of signals less than 10Hz, it's generally better to measure the period of the signal. When set to this mode, the Micromite will measure the number of milliseconds between sequential rising edges of the input waveform. The value is updated on the low to high transition so if your signal has a period of (say) 100 seconds you must wait for that amount of time in order for the PIN() function to return an updated value.

The COUNT pins can also count the number of pulses on their input. When a pin is configured as a counter (eg, **SETPIN 15,CIN**), the counter will be reset to zero and the Micromite will then count every low to high voltage transition. The counter can be reset to zero again by executing the SETPIN command a second time (even though the input was already configured as a counter).

The response to input pulses is very fast and the Micromite can count pulses as narrow as 20ns (although the maximum frequency of the pulse stream is still limited to 200kHz).

Digital outputs

All I/O pins can be configured as standard digital outputs. This means that when an output pin is set to logic low it will be pulled to 0V and when set high it will be pulled to 3.3V. In MMBasic, this is done with the PIN command. For example PIN(15) = 0 will set pin 15 low, while PIN(15) = 1 will set it high.

When operating in this mode, a pin is capable of sourcing 10mA which is sufficient to drive a LED or other logic

circuits running at 3.3V. Pins marked as **5V** have a couple of additional properties that make it easy to connect to 5V circuitry. First, as inputs, they can be directly connected to a circuit that generates up to 5V without the need for voltage dropping resistors. These pins can also be set up to be open collector outputs.

The term 'open collector output' means that the output driver will pull the output low (to zero volts) when the output is set to a logic low but will go to a high impedance state when set to logic high. If you then connect a pull-up resistor to 5V on the output, the logic high level will be 5V (instead of 3.3V using the standard output mode). The maximum pull-up voltage in this mode is 5.5V.

Pulse width modulation

The PWM (Pulse Width Modulation) command allows the Micromite to generate square waves with a program-controlled duty cycle. By varying the duty cycle, you can generate a program-controlled output voltage and this could in turn be used to control external devices that require an analog input (power supplies, motor controllers, etc).

Five PWM outputs are available in two groups and the frequency of each group can be independently set from 20Hz to 500kHz (see Pt.1 last month). The duty cycle for each output can also be independently set from 0-100% with 0.1% resolution when the frequency is below 25kHz. Above 25kHz, the resolution is 1% or better up to 250kHz.

When the Micromite is powered up or the PWM OFF command is used the PWM outputs will be set to high impedance (they are neither off nor on). So, if you want the PWM output to be low by default (zero power in most applications), you should use a resistor to pull the output to ground when it is set to high impedance. Alternatively, if you want the default to be high (full power), you should connect the resistor to 3.3V.

Interrupts

Interrupts are a handy way of dealing with an event that can occur at an unpredictable time. An example is when the user presses a button. You could insert code after each statement to check if a button has been pressed but an interrupt makes for a cleaner and more readable program.

When an interrupt occurs, MMBasic executes a special section of code and then returns to the main program when it has finished. The main program will be unaffected by this interrupt and will then carry on as normal.

I/O pins designated as INT (see Fig.1 in Pt.1 last month) can be configured to generate an interrupt using the SETPIN command. Many interrupts (including the tick interrupt, IR interrupt, etc) can be active at any one time. Interrupts can be set to occur on a rising or falling digital input signal (or both) and will cause an immediate branch to a specified line number, label or user defined subroutine. The target can be the same or different for each interrupt.

If two or more interrupts occur at the same time, they are processed in order of pin numbers (ie, an interrupt on pin 2 will have the highest priority). All other interrupts are disabled during the processing of an interrupt until the interrupt routine returns with an IRETURN.

During an interrupt (and at all other times), the state of the pin that caused the interrupt can be determined using the PIN() function. For most programs, MMBasic will respond to an interrupt in under 50µs. To prevent slowing the main program too much, an interrupt should be short and exit as soon as possible. You must also remember to disable an interrupt when you have finished with it – background interrupts can cause bugs which are difficult to find.

Timing

MMBasic maintains an internal clock which will provide the current date and time using the DATE$ and TIME$ functions. You can also set the date/time by assigning the new date and time to these functions. This makes it easy to time events and control external circuitry that needs timing.

On power-up, the calendar starts from midnight on the 1st January 2000 but by using the RTC command (see above) you can correct the time maintained by a PCF8563 real time clock (RTC) chip.

Another timing function is the PAUSE command which will freeze the execution of the program for a specified number of milliseconds. So, to create a 12ms wide pulse, you could use the following:

```
SETPIN 4, DOUT
PIN(4) = 1
PAUSE 12
PIN(4) = 0
```

You can also create a pulse using the PULSE command. This can generate very narrow pulses (eg, 20µs) or long pulses lasting up to several days. Long pulses are run in the background and the program will continue uninterrupted.

Another useful feature is the TIMER function which acts like a stopwatch. You can set it to any value (usually zero) and it will count upwards every millisecond.

A timing function is also provided by the SETTICK command. This command will generate an interrupt at regular intervals (specified in milliseconds). Think of it as the regular 'tick' of a watch.

As an example, the following code fragment will print the current time and the voltage on pin 2 every second. This process will run independently of the main program which could be doing something completely unrelated:

```
SETPIN 2, AIN
SETTICK 1000, DOINT
DO
  ' main processing loop
LOOP

DOINT:
PRINT TIME$, PIN(2)
IRETURN
```

The second line sets up the 'tick' interrupt, the first parameter of SETTICK is the period of the interrupt (1000ms) and the second is the label of the interrupt code. Every second (ie, every 1000ms), the main processing loop will be interrupted and the program at the label DOINT will be executed.

Up to four 'tick' interrupts can be set up. This type of interrupt has the lowest priority.

Serial communications

Two serial ports are available for asynchronous serial communications. These are labelled COM1: and COM2:

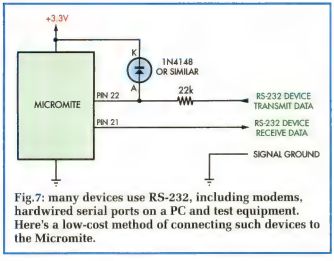


Fig.7: many devices use RS-232, including modems, hardwired serial ports on a PC and test equipment. Here's a low-cost method of connecting such devices to the Micromite.

and after being opened they have an associated file number.

You you can use any commands that operate with a file number to read and write to/from a serial port. A serial port is also closed using the CLOSE command.

The following is an example:

```
OPEN "COM1:4800" AS #5
PRINT #5, "Hello"
dat$ = INPUT$(20, #5)
CLOSE #5
```

This opens COM1: with a speed of 4800 baud and then transmits the string "Hello". It then gets up to 20 characters from the port and closes it. This isn't a very useful example but it does show how simple it is to use a serial port.

By the way, the syntax was defined by Bill Gates in the 1970s – MMBasic tries to keep as close to Microsoft BASIC as possible.

The baud rate can be up to 230,400 on COM1 and 19,200 on COM2. There are other options that can be applied including nine data bits, two stop bits and data enable for RS-484 compatibility. These options are explained in greater detail in the Micromite User Manual.

The signal polarity is standard for devices running at TTL voltages (see section below for RS-232 voltages). Idle is voltage high, the start bit is voltage low, data uses a high voltage for logic 1 and the stop bit is voltage high.

These signal levels allow you to directly connect to devices like GPS modules (which generally use TTL voltage levels).

Low-cost RS-232 interface

The RS-232 signalling system is used by modems, hardwired serial ports on a PC, test equipment etc. It is the same as the serial TTL system used on the Micromite with two exceptions:

(1) The voltage levels for RS-232 are +12V and -12V, whereas TTL serial uses +3.3V and 0V.

(2) The signalling is inverted (ie, the idle voltage is -12V, the start bit is +12V etc).

Cheap RS-232-to-TTL converters can be purchased on the internet. However, if cable lengths are kept short, you can directly connect the Micromite to RS-232 provided you add a resistor and a diode as shown in Fig.7.

First, the signalling polarity needs to be inverted. On the Micromite, COM1: can be specified to invert both the transmit and receive signals (the **INV** option), so that's an easy fix.

For the receive data (ie, the ±12V signal from the remote RS-232 device), the signal voltage can be limited using a 22kΩ series resistor and a diode that clamps the maximum positive signal level to the +3.3V rail (there is no internal clamp diode as it is a 5V tolerant input). The Micromite's input impedance is very high so the resistor will not cause a voltage drop. However, it does mean that when the signal swings to the maximum +12V, it will be safely clipped by the diode. Similarly, when it swings to -12V it will be clipped by an internal protection diode on pin 22 of the Micromite.

The transmit signal (ie, from pin 21) can be directly connected to the input of the RS-232 device. The Micromite will only swing the signal from 0V to +3.3V but most RS-232 inputs have a threshold of about +1V so the Micromite's transmit data will still be interpreted as a valid signal.

These measures break the rules for RS-232 signalling but it should work fine if you only want to use it over a short distance (a metre or two). Once it's connected, all you need do is open COM1: with the invert option, eg:

```
OPEN "COM1: 4800, INV" AS #1
```

I²C communications

The Inter Integrated Circuit (I²C) bus was developed by Philips (now NXP) to transfer data between ICs. Many devices can now communicate using I²C and it's especially useful for communicating between Micromites.

Two signals are used for communications: (1) the data line (called SDA) and (2) the clock line (called SCL). Both should be pulled up to +3.3V or +5V (depending on the device) by resistors (typically 4.7kΩ). Both the Micromite and the other device signal each other by pulling these lines low.

Within MMBasic, there are commands to open the connection, write data, read data and close the connection. Normally, the Micromite would operate in master mode so that it controls the communications but it can also work in slave mode. Full details on the relevant commands are in the Micromite User Manual.

Fig.8 shows an example of I²C being used for communications between two Micromites, in this case to offload the keypad and LCD functions from the master device. Taken together, these functions use up to 14 I/O pins so it's convenient to assign responsibility for handling them to a slave Micromite as shown. After all, a Micromite chip doesn't cost very much.

Using just a few lines of code, the master Micromite can query the slave Micromite to determine if a key on the keypad has been pressed. It can also send some data to the slave to be displayed on the LCD. Fig.9 shows the code that needs to be running on the slave, while Fig.10 is all that you need on the master to update the display and get the last key pressed on the keypad (just six lines in total).

1-Wire & SPI communications

To round out the communications facilities, MMBasic also includes support for 1-Wire and SPI communications.

The 1-Wire protocol was developed by Dallas Semiconductor to communicate with chips using a single signalling line. It's commonly used for communicating with the

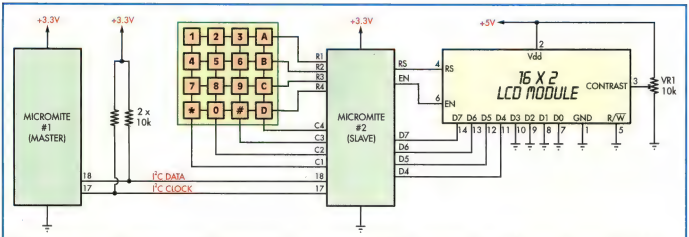


Fig.8: this diagram illustrates how to connect two Micromites together so that the LCD and keypad interfaces can be offloaded to the second (slave) Micromite using I²C communications. Together these functions use up to 14 I/O pins so this is a handy and low cost method of freeing up I/O pins on the master Micromite.

DS18B20 temperature sensor but MMBasic has an inbuilt function for dealing with that device that's much more convenient to use. Other 1-Wire devices include memory chips and security devices.

SPI has been around a long time and many devices use that protocol including memory chips, accelerometers, environment sensors and a host of others.

Rather than go into the detail here, you can download the Micromite User Manual which provides a detailed explanation of the commands and functions which support these protocols.

Defined subroutines & functions

MMBasic allows you to define your own subroutines and functions in your programs. These are modern programming techniques that are useful in organising programs so that they are easy to modify and read. They will be new to many readers so we will take a little time to explain how they work.

A defined subroutine or function is simply a block of programming code that is self-contained and can be 'called' from anywhere within your program. It is the same as if you have added your own command or function to the language.

For example, assume that you would like to have the command FLASH added to MMBasic and its job would be to flash a LED on pin 2. You could define a subroutine like this:

```
Sub FLASH
  SETPIN 2, DOUT
  Pin(2) = 1
  Pause 100
  Pin(2) = 0
End Sub
```

With this subroutine in place, you now just use the command FLASH to flash the LED, eg:

```
IF A < B THEN FLASH
```

Defined subroutines can have 'arguments' (sometimes called parameter lists). In the definition of the subroutine they look like this:

```
Sub MYSUB (arg1, arg2$, arg3)
  <statements>
  <statements>
End Sub
```

When you call the subroutine you can assign values to the arguments, eg:

```
MYSUB 23, "Cat", 55
```

In this case, variable **arg1** will have the value "23", **arg2$** the value "Cat", and so on. The arguments act like ordinary variables but they exist only within the subroutine and will vanish when the subroutine ends. You can have variables with the same name in the main program and they will be different from arguments defined for the subroutine (at the risk of making debugging harder).

Local variables

Inside a subroutine, you will need to use variables for various tasks. In reusable code, you don't want the name you chose for any such variable to clash with a variable of the same name in the main program. This can be ensured by defining a variable as LOCAL.

For example, this is our FLASH subroutine again but this time we have extended it to take an argument (nbr) that specifies how many times to flash the LED:

```
Sub FLASH ( nbr )
  Local count
  SETPIN 2, DOUT
  For count = 1 To nbr
    Pin(2) = 1
    Pause 100
    Pin(2) = 0
    Pause 150
  Next count
End Sub
```

The counting variable (count) is declared as local which means that (like the argument list) it only exists within the subroutine and will vanish when the subroutine exits. You can have a variable called **count** in your main program and it will be separate from the variable **count** in your subrou-

```
LCD INIT 2, 3, 4, 5, 6, 7
KEYPAD pad, PadI, 9, 8, 14, 15, 16, 24, 25, 26
I2C SLAVE OPEN &H26, 0, 0, WriteD, ReadD          ' slave's address is 26 (hex)

DO                                                ' the program loops forever
  WATCHDOG 1000                                   ' this will recover from errors
LOOP

ReadD:                                            ' received a message
  I2C SLAVE READ 18, msg$, recvd                  ' get the message
  LCD ASC(msg$), ASC(MID$(msg$, 2, 1), MID$(msg$, 3)   ' display it
  IRETURN                                         ' return from the interrupt

WriteD:                                           ' request from the master
  I2C SLAVE WRITE &H26, pad                       ' send the last key press
  IRETURN                                         ' return from the interrupt

PadI:                                             ' key down on the keypad
  IRETURN                                         ' we do not do anything
```

Fig.9: this is the program running on the slave Micromite which is handling an LCD display module and a 4x4 keypad. The program waits for data, in which case it will send it to the LCD display. It also waits for a request from the master and in that case it will send the last key pressed on the keypad. The watchdog timer is set running so that if an error occurs the Micromite will automatically restart itself.

tine. If you do not declare the variable as local, it will be created 'globally' in your program and be visible in the main program and subroutines, just like a normal variable.

You can define multiple items with the one LOCAL command and if an item is an array, the LOCAL command will also dimension the array (ie, you do not need the DIM command).

Defined functions

Defined functions are similar to defined subroutines, the main difference being that the function is used to return a value in an expression. For example, if you wanted a function to select the maximum of two values you could define:

```
Function Max(a, b)
  If a > b
    Max = a
  Else
    Max = b
  EndIf
End Function
```

You could then use it in an expression, as follows:

```
SetPin 1, 1 : SetPin 2, 1
Print "The highest voltage is" Max(Pin(1), Pin(2))
```

The rules for the argument list in a function are similar to subroutines. The only difference is that brackets are required around the argument list when you are calling a function (they are optional when calling a subroutine).

To return a value from the function, you assign a value to the function's name within the function. If the function's name is terminated with a '$' the function will return a string, otherwise it will return a number. Within the function, the function's name acts like a standard variable.

As another example, let's assume that you need a function to format time in AM/PM format. The code is as follows:

```
Function MyTime$(hours, minutes)
  Local h
  h = hours
  If hours > 12 Then h = h - 12
  MyTime$ = Str$(h) + ":" + Str$(minutes)
  If hours <= 12 Then
    MyTime$ = MyTime$ + "AM"
  Else
    MyTime$ = MyTime$ + "PM"
  EndIf
End Function
```

As you can see, the function name is used as an ordinary local variable inside the subroutine. It's only when the function returns that the value assigned to MyTime$ is made available to the expression that called it. This example also illustrates that you can use local variables within functions just like subroutines.

Passing arguments by reference

If you use an ordinary variable (ie, not an expression) as the value when calling a subroutine or a function, the argument within the subroutine/function will point back to the variable used in the call. In addition, any changes to the argument in your routine will also be made to the supplied variable. This is called passing arguments by reference. For example, you might define a subroutine to swap two values, as follows:

```
Sub Swap a, b
  Local t
  t = a
  a = b
  b = t
End Sub
```

In your calling program, you would use variables for both arguments as follows:

```
s$ = chr$(1) + chr$(1) + "Hello Micromite"
I2C OPEN 100, 1000
I2C WRITE &H26, 0, 18, s$
I2C READ &H26, 0, 1, pad
IF MM.I2C THEN ERROR "Slave did not respond"
I2C CLOSE
```

Fig.10: this is all that is needed to send data to the LCD connected to the slave and get the last key pressed on they keypad. First an 18-character string is built up – the first character is the line on the LCD to place the text and the second is the column position. The rest of the string is the data to display. After that has been sent, the program gets one byte from the slave which is stored in the variable 'pad'. This is the value of the last key pressed on the keypad.

Swap nbr1, nbr2

The result will be that the values of nbr1 and nbr2 will be swapped.

Unless you need to return a value via the argument, you should not use an argument as a general-purpose variable inside a subroutine or function. This is because another user of your routine may unwittingly use a variable in their call and that variable will be 'magically' changed by your routine. It's much safer to assign the argument to a local variable and manipulate that instead.

Resetting MMBasic

It's possible to get MMBasic into a state where Ctrl-C on the console will not be recognised, eg, if you set a security PIN and then forget the number. In this case, MMBasic can be reset to its original configuration using either of two methods:

(1) reprogram the chip with the Micromite firmware using a PIC32 programmer; or

(2) short pins 11 & 12 together while applying power. Following this, you then need to wait a couple of seconds and remove the power and the short.

Either method will result in the program memory and saved variables being completely erased and all options (security PIN, console baud rate, etc) will be reset to their initial defaults.

Coming next month

Next month, we will describe the SILICON CHIP ASCII Video Terminal. This is a stand-alone serial terminal that you can attach to a Micromite to create and edit your program or you can just use it to display data.

The ASCII Video Terminal can drive a VGA or composite monitor and will accept a standard PS2 keyboard for input, so it is the perfect companion for the Micromite. It connects to the Micromite via a serial interface and can also connect to your PC via USB. **SC**

Where To Get The Micromite

A pre-programmed Micromite chip is available for $15 plus p&p from the SILICON CHIP Online Shop (includes the 47µF capacitor). MMBasic and a User Manual are also available on the SILICON CHIP website (free of charge).

By LEO SIMPSON

Fast Ethernet connections via 230VAC mains

Is your WiFi router not good enough to run your smart TV? That's a common problem and the one effective solution is to have a direct Ethernet connection from your modem/router to your TV. But there is now another way and that is to use Ethernet power line adapters. These will let you have an Ethernet connection anywhere in your home.

FOR MOST PEOPLE, a WiFi router in their home gives effective wireless connection to their laptop and tablet computers, smart phones etc. But WiFi is not always effective for connection to a smart TV. While the TV may well be able to "recognise" the WiFi connection, it will simply not be reliable or fast enough to allow video services such as iView, SBS On-Demand, Netflix, Bigpond movies and a host of other internet video services.

I have two smart TVs in my home (Panasonic and LG) and I went through a lot of frustration trying to get them to work properly over WiFi. It is hard enough to go through the tedious initialisation process to get the TVs to actually communicate and recognise the connection but getting reliable video transfer is another thing entirely.

With my two smart TVs, it simply did not work, even if the modem/router was in the same room as the TV.

So much for smart technology.

I contacted one of the engineers at Panasonic and was told that the only guaranteed method of feeding internet video to a smart TV was to have my home wired for Ethernet. Because of the cost and awkardness of doing this, I put this off for quite a while but eventually relented as my wife was keen to watch iView etc. It involved running cables in and through cavity walls for a considerable distance, under floors, over and under lintels for a door and window in a cavity wall and quite a lot of cursing, as I and the electrician persevered with the task.

Because I wanted to be able to run the modem-router in either my study or a more centrally located under-stair space in my house, I broke the long cable runs and had a patch panel installed in the under-stair location. At the end of it all, I had reliable Ethernet communications on the ground floor of my house (and my wife could happily view services such as ABC's iView and SBS On-Demand). But I still had to rely on WiFi if I wanted to use my laptop etc on the top floor or basement workshop.

That was OK until WiFi's speed limitations became apparent. Because my large house is of double-brick construction with a massive concrete floor for the upper section, even an undemanding WiFi connection can be quite difficult – that is why I wanted the alternative locations for the modem. So I just had to live with that. There there was no way I was going to extend the Ethernet cables to those floors. It was just too difficult to consider, with concrete floors and more cavity walls to be penetrated.

The Edimax HP-5101K Nano Power Line Adaptor kit makes it easy to create a 100Mbps Ethernet link between any two power points in your home or office. It sells for just $99 and is available from Jaycar stores (Cat. YN-8352).

Fast Ethernet over power.

Within the last 12 months or so, another way to make reliable high-speed Ethernet connections has become available – Ethernet over Power Line. Now Ethernet over Power Line is not new but this latest iteration is really fast at 500Mbps. This is much faster than the 6Mbps (or so) rate required for on-line video services such as iView.

Jaycar has just such a product with the Edimax HP-5101K 500Mbps Nano Power Line Adaptor kit. This essentially consists of what look like two identical plugpacks, each with a standard Cat5 socket on the underside. You plug in one close to your modem/

Ethernet Over Power Lines: How Does It Work?

Ethernet over power lines is nothing new. We reviewed the NetComm NP210 in October 2005 but a lot has changed since then.

For a start, those devices were capable of a maximum speed of 14Mbps which is slower than ADSL2 let alone a proper wired Ethernet link, which these days is usually 1000Mbps (Gigabit Ethernet). The new standard, with up to 500Mbps, is much more competitive and fast enough to copy large files from computer to computer.

But they've also done a lot of work to ensure interoperability between different brands of Ethernet Over Power adaptor and ensure that interference is not an issue, even if your neighbour is also using such devices.

The relevant standard is IEEE 1901, published in 2010. Compliant devices use one of two signalling techniques, either FFT or wavelet-based orthogonal frequency-division multiplexing (OFDM) modulation. While not a requirement of the standard, most good, modern Ethernet Over Power adaptors should support both techniques and thus you are not required to stick with a single brand or model to get connectivity throughout your home or office.

OFDM is in fact a similar scheme to that used for ADSL, WiFi and terrestrial digital TV (DVB-T). Data is transmitted on multiple different frequencies simultaneously, with the carriers all being orthogonal to eliminate crosstalk. These devices typically use a signalling frequency in the range of 2-68MHz.

On top of the OFDM, IEEE 1901-compliant Ethernet Over Power adaptors implement an "Inter-System Protocol" which allows units to discover other nearby networks that could potentially conflict and share the available bandwidth between them in order to prevent interference from affecting reliability.

Essentially, the way that this works is that adaptors periodically broadcast a signal along the power lines indicating their presence. Other adaptors pick up this signal and then negotiate for a time slice during which they have dedicated use of the available bandwidth. In other words, they co-exist by means of a time-division multiplexing (TDM) scheme.

The same protocols can also be used for long-distance signalling, ie, Broadband Over Power Lines but we remain sceptical as to whether this is a practical proposition, especially with regards to interference, both between customers sharing the same power lines and with the power lines radiating RF and possibly interfering with other wireless devices.

router and connect it with a short Ethernet cable. Elsewhere in your house, say behind your smart TV, you plug in the other Power Line Adaptor and connect it to your TV with a short Ethernet cable.

If the modem and your TV are both powered up, the lights on the adaptors will immediately indicate that you have a viable Ethernet connection and you are ready to go. It's that simple.

RF interference

I was concerned about RF interference from the data being superimposed on the 230VAC mains wiring in my home and went around with a radio on the AM & FM bands but could find little evidence of it. Indeed, there was far more interference from my cordless phone system and to a lesser extent, from the Ethernet cables themselves.

The frequency bands used for the data transmission on the mains wiring are from 2-28MHz and 30-66MHz, ie, slap bang over the shortwave bands. A shortwave receiver indicated low interference from the mains wiring when the adaptors were in idle mode but interference is severe when data is being transferred. This will be a problem for anyone who wants to use the shortwave bands.

Of course, to use the Nano Power Line Adaptors you really do need to have them powered all the time, as well as your modem/router. But their power consumption is low, about 500mW each on standby (for a total of 1W) and up to 2.4W each at full load. That compares well with my Bigpond modem/router which pulls 6W and gets quite warm into the bargain.

I did a comparison of the download rates for on-line video for both my Ethernet connection and Ethernet via the Nano Adaptors. The result was the same at 6Mbps which is probably limited by my ADSL2 connection. That is far below the limit of the Nano Adaptors 100Mbps ports.

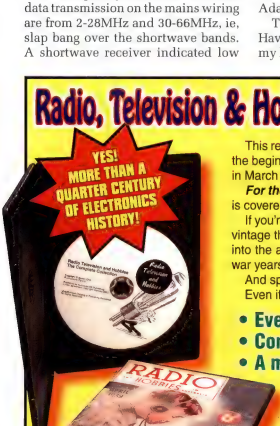
Then there is the cost comparison. Having the Ethernet wiring installed in my home was quite expensive, requiring a substantial amount of Cat6 cable, various Ethernet wall panels and most of all, the labour cost for the electrician. It all came to about $500 and even then it wasn't a complete solution.

On the other hand, a pair of Nano Adaptors means that I can have Ethernet virtually anywhere there is a 230VAC power point; even in the garage or store-room. I will just leave one Nano Adaptor permanently connected to the modem/router and the other can be moved from room to room, as needed. However, since the cost of the Edimax kit, with a pair of adaptors, is just $99, you could easily justify having two or more pairs permanently set up in your home, wherever you might need to have Ethernet for high-speed file transfer or whatever.

Overall, I wish this product had been available at the time I had the Ethernet wiring done. It would have saved a lot of time and expense and ultimately, would have been a more complete solution.

The Edimax HP-5101K 500Mbps Nano Power Line Adaptor kit is available from all Jaycar stores and resellers (Cat. YN-8352). SC

Radio, Television & Hobbies: the COMPLETE archive on DVD



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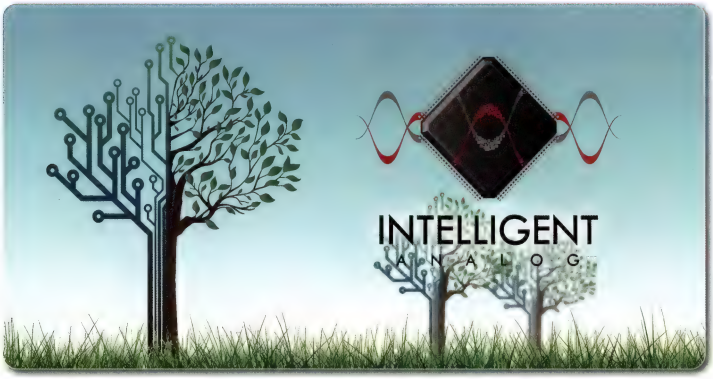

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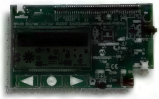

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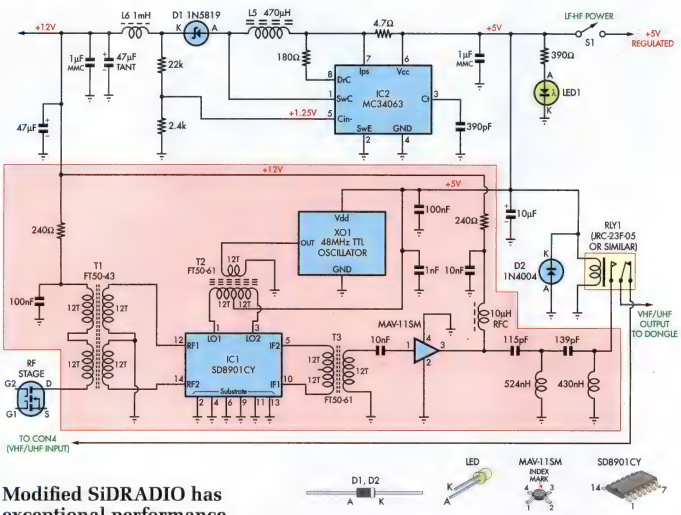
CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



Modified SiDRADIO has exceptional performance

This modified version of the SiDRADIO project described in the October to December 2013 issues has a performance comparable with an updated Kenwood 820S on receive; it can resolve signals down to at least 1µV on the HF bands. It uses a very similar RF amplifier to the SiDRADIO project but with the dual-gate FET preselector tuned by a 3-gang 200pF per section tuning capacitor with built-in slow motion drive (ie, instead of VC1). This meant that I could use one section on the higher frequencies and switch in up to 600pF on the low-frequency bands.

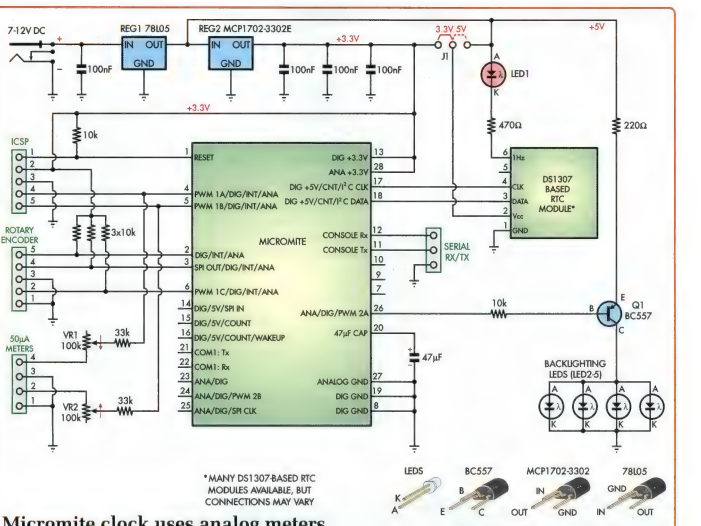
The preselector output is coupled through an Amidon FT50-43 ferrite toroid transformer (T1) with an impedance match of 200Ω to 50Ω. The transformer is quadifilar-wound with 12 turns of 0.3mm enamelled copper wire.

The mixer uses a double balanced SD8901 mixer IC instead of the originally specified SA602D or SA612D. This is fed with a 48MHz high power TTL oscillator (XO1). These oscillators can often be obtained from old computer boards.

The SD8901 mixer is fed to a MMIC MAV-11SM IF amplifier with a gain of about +15dB, followed by a high-pass filter with a sharp cut-off at 48MHz. This filter also matches the 50-ohm impedance of the MAV-11SM to the 75-ohm input of the DAB unit. This works extremely well, especially so once the BNC input socket was grounded properly. The noise floor is slightly higher than for my Kenwood receiver but it performed well even during contests and 'pile-ups' on the amateur bands and is fine for all other uses too.

The local oscillator coupling transformer (T2) and the mixer output transformer (T3) were trifilar wound on Amidon FT50-61 toroid cores, with each transformer having 12 turns. This has proved OK from 200kHz to 40MHz, so far.

Both the SD8901 mixer and MMIC IF amplifier were mounted on a small surface mount board. The switching between LF and VHF/



Micromite clock uses analog meters for the time display

This has to be most novel clock project we have ever seen. It uses two 50µA analog meter movements to indicate 24-hour time. These meter movements have had their scales changed to read 0-23 hours and 0-59 minutes.

The two meter movements are driven by a Micromite, the same programmed microcontroller presented in May 2014 and continuing elsewhere in this issue. Time information for the Micromite comes from a DS1307 real-time clock (RTC) module. To add to the quirkiness of the circuit, the two meter movements are each back-lit by two LEDs.

On first power up, the meters will sweep from 0 to full scale twice. If the DS1307 RTC has not had the time set yet, the seconds LED (LED1) will be on. To set the time, press and hold the rotary encoder switch down for more than three seconds. This will allow the time to be set using the rotary encoder. A second press of the rotary encoder button will set the minutes and a third press will save the time to the DS1307 and LED1 will start to flash at 1Hz.

A short press of the rotary encoder button will then allow the meter backlight brightness to be set using the rotary encoder. In this mode a

continued on page 82

UHF is done by an SPDT reed relay run from the up-converter's internal 12V DC supply, controlled by the front-panel band switch.

When the unit was tested, after a few teething troubles, the results were pleasing. I found myself winding down the output of my Marconi 2002 signal generator below 1µV and still getting a signal.

Indeed, for casual shortwave and amateur radio listening, I use the SDR instead of my big Kenwood 820S transceiver. The only downside of the SDR is a very slightly higher noise floor; as far as signal breakthrough is concerned and with regard to cross-modulation, it actually seems better. This is probably because of the more advanced mixer in the SDR. I have received CW and SSB from all over the world on both 7MHz and 14MHz.

The local oscillators are stable and frequency correction was slight and easily set up using WWV. The only limitation at the low-frequency end is the 48MHz notch filter which has to be sharp as possible to stop severe gain reduction below 500kHz or so.

Clifford Wright, ZL1BDA, Helensville, NZ.

Clifford Wright is this month's winner of a $150 gift voucher from Hare & Forbes

Arduino-compatible alarm clock has large LED dot matrix display

This Arduino-based alarm clock shows the day, time and date on a large Freetronics LED dot matrix display (DMD). An alarm function is also available.

The hardware is a ATmega328P microcontroller with a real-time clock (RTC) module, a piezo module and some buttons to set and silence the alarm. The Freetronics LED display is connected to the microcontroller via the supplied connector.

In the global section of the code, all the required libraries and declarations are set up and ready to be used. There is also several sections that set up the RTC and DMD. As the sketch starts in the "setup" routine, the RTC is refreshed then the DMD is set up.

At lines 116-125 you can set the time stored in the RTC. Note that once you have changed these values you need to 'uncomment' line 125, flash the microcontroller then 'comment' line 125 again and flash the chip once more. If this is not done every time the micro is reset, it will reset the RTC back to the time set by the user. After that section of code, the pins are set up.

The AlarmSetPin and SnoozePin are set to INPUT_PULLUP. This means no external pull-up resistors are required. This also means that the pins will read as zero when the connected buttons are pressed. The set-up is then complete and 418 lines of functions follow. These instruct the DMD what to display.

Each one operates in the same way. This is an example of what each one looks like just with the values different.

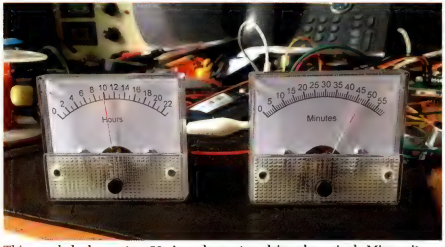
```
case 1:
dmd.drawString( 1,0, "Sun,", 3, GRAPHICS_NORMAL );
break;
```

In each instance, the *case* statement checks the time value from the RTC and if it matches the expected value, tells the DMD what to print. This is done with the command *dmd.drawString* followed by placement values then the *String*, the maximum number of characters then *GRAPHICS_NORMAL* which tells the DMD to turn only the required LEDs on. This sequence is repeated for every value to be displayed. This is dictated by the way in which the DMD library works.

This can be change to suit the user's preferences. In the main loop it runs a command called runClock(). This runs several more commands:

```
drawDay();
drawDate();
drawHour();
drawCol();
drawMinute();
CheckAlarm();
```

Each one of these is calls one of the diplay functions mentioned earlier, except for CheckAlarm(), which determines whether the alarm should go off, which is set on lines 592 and 593. On line 592 you choose which day(s) the alarm is set for. The values are 1 = Sunday, 2 = Monday, 3 = Tuesday, 4 = Wednesday, 5 = Thursday, 6 = Friday, 7 = Saturday. Use the 'or' command '|' to set the



This novel clock uses two 50µA analog meters driven by a single Micromite microcontroller. The time shown is 10.47!

Micromite Clock . . . from p81

second press saves the brightness level to EEPROM in the DS1307. If the power is lost, the clock will get the time from the DS1307 RTC and the brightness setting from the RTC's EEPROM.

The backlights are diffused LEDs of your colour choice. These are fitted to the meters by drilling two appropriately sized holes (3mm or 5mm) at the bottom of the two meters. The meter scales were done using MeterBasic from **www.tonnesoftware.com/meterbasicdownload2.html**

The "hours" readout meter is connected to pins 4 & 3 of CON2, while the "minutes" readout meter is connected to pins 2 & 1 of the same connector. Remember that the meters are polarised, so the negative connections of the meters go to pins 1 & 3 of CON2.

Connections to the rotary encoder are 1 & 2 for the switch, 3 is common, 4 is left and 5 is right.

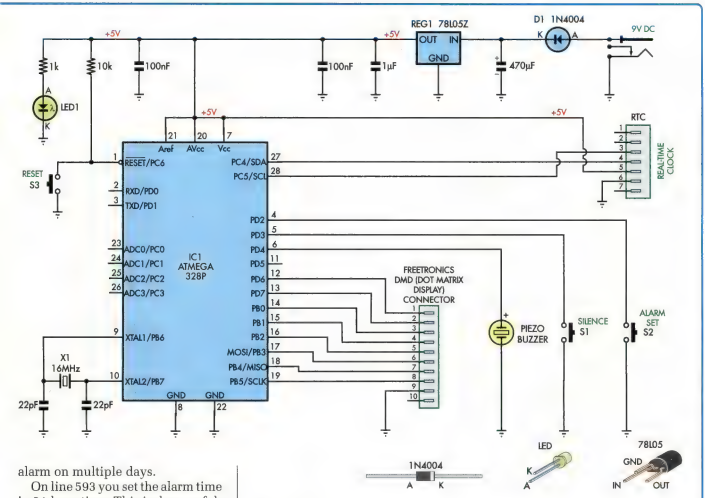
Link J1 sets the supply voltage for the DS1307 module to 3.3V or 5V.

The PWM duty cycle and thus the displayed time is updated once every minute and can be monitored via the serial port. The 50µA meters are driven by a pulse width modulated signal from the Micromite and the full scale deflection will need to be adjusted by the associated 100kΩ trimpots VR1 & VR2. If the backlight brightness is adjusted, this can also be monitored via the serial port.

The ICSP programming connector can used to update the Micromite firmware but this can be omitted if not required.

The software, Mclock-v3.bas, can be downloaded from the SILICON CHIP website.

John Gerrard,
Christchurch, NZ. ($75)



alarm on multiple days.

On line 593 you set the alarm time in 24-hour time. This is done as follows (inside the if command); "hour == 18 && minute == 05", changing 18 and 05 for the hour and minute.

Then it checks to see if the alarm is active and if so, it proceeds to set up the SnoozePin and in a "while" statement it runs the command AlarmSequence which sounds the buzzer and flashes the DMD until the Silence button is pressed.

The sketch uses 11,674 bytes of data from a maximum of 32,256 bytes (for the ATmega328P). This allows for plenty of room to add more alarms or more code to the sketch. This is written in the Arduino IDE which uses the C language. The software. MastClock.ino may be downloaded from the SILICON CHIP website.

Editor's comment: note that the timekeeping accuracy will depend on the precision of the 16MHz crystal and this circuit has no provision for oscillator trimming.

This could probably be added by connecting a small value trimmer capacitor in parallel with the 22pF crystal load capacitor connected to pin 9, the input of the oscillator amplifier.

Jed Hodson,
Galong, NSW. ($60).

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By NICHOLAS VINEN

100W Hybrid Switchmode/ Linear Bench Supply, Pt.3

In this third and final instalment on our 40V/5A DC input bench supply, we take the completed PCB and fit it into the case, along with the chassis-mounting hardware and wiring. We also answer some reader questions about the supply.

OVER THE LAST two months, we have described the operation of our new bench power supply and given the construction details for the PCB. This supply is somewhat unusual in that it runs off a 12-24V input such as a 12V battery or old PC or laptop power supply. It also combines a switchmode buck/boost circuit with a linear regulator to give a wide output voltage range, low noise and fast-acting current limiting.

It's built into a case from Altronics which will be supplied with two pre-fitted LED panel meters for dual metering, ie, simultaneous voltage and current read-out. The voltage and current are adjustable in 0-40V and 0-5A ranges using multi-turn pots for accuracy. There is also a pushbutton to view the current limit setting to make it easier to adjust. Since the current limiting is linear in nature, the supply can be used as a voltage or current source.

Now let's go over the final steps to complete and test the power supply.

Preparing the panel meters

In addition to trimming the leads and fitting plugs to suit the connectors on the PCB, we need to tweak the two LED panel meters slightly. This is best carried out by first removing them from the front of the case, which is done by squeezing the clip on one side and then pushing that side forward until it pops out the front. You can then squeeze in the clip on the other side and remove the unit.

The actual panel meter is inside a plastic housing with a rear plate that's held on by four more clips, two on either side. Gently push these in with the tip of a flat-blade screwdriver; you don't want to snap the plastic. Once you've popped one side up, the rear panel should then come off easily and you can pull the PCB assembly out.

The first thing to do is remove the short circuit between pins 2 & 3 of the

header connector. This can be done by simply running a hot iron between them a couple of times, taking care not to damage any of the surrounding components. Do this for both panel meters.

We also need to change the position of the decimal point on one panel meter. By default they read up to 199.9 which suits us for voltage but for current, we need it to read up to 19.99, ie, with the decimal point between the second and third digits rather than third and fourth.

This modification is done by clearing a solder shorting 'link' on the board and making another one. These solder 'link' positions are between an exposed track and three small rectangular pads near R4 at lower-right, next to the MKT capacitor. Left-to-right they are labelled S, B and Q (see the instruction sheet supplied with the meter). You will need to clear the short from track L to pad S and instead short track L to pad B. That's just for the ammeter; leave the other meter (for voltage) with L and S connected.

If you've installed trimpots VR7 & VR8 on the PCB you can put the meters back into their plastic housings and snap the backs on. Otherwise, leave the backs off as you'll need access to the meter trimpots later.

Connecting cables

The next step is to fit polarised header plugs to the bare ends of the supplied hook-up wires. Trim them all to the same length of around 100mm, then strip the ends and crimp them into the pins which are supplied with the polarised header plugs. This is done by folding the two small metal leaves over the exposed portion of the wire and the larger ones over the insulated section and then squeezing them down hard with needle-nose pliers to hold the wires in place.

Note though that unless you have a specialised crimping tool for this kind of pin, this will be insufficient to retain the wire so you will then also need to solder the exposed copper in place. Use only a small amount of solder and don't get any on the outside of the pin or it won't go into the plastic block.

Once all four wires have pins attached, slide them into the slots in the header block and push them in until they click into place. The wires must be ordered as shown in Fig.7 last month (see photo below).

If you get them wrong, you will have to use a small tool to push gently on

Running The Supply From A Higher Voltage

We've already had enquiries as to whether it's possible to run this unit from a higher voltage DC supply and the answer is yes, with a few small modifications. As stated in the previous articles, old laptop and PC power supplies are quite suitable and will typically supply 12-17V, while a typical 6-cell lead-acid battery is also suitable, giving a supply of 13-14.5V while being charged and 12-13V the rest of the time.

However if you have a 24V (12-cell) lead-acid battery or battery bank, as used in many trucks, boats, caravans and off-grid power systems, it's not a good idea to connect the bench supply as originally designed. That's because the battery will approach 30V during charge, well above the recommended maximum supply of 24V.

There are a few simple changes which will allow operation up to 40V, although we recommend keeping the supply below 30V to avoid excessive dissipation in REG1 due to the relatively high current drawn by the LED panel meters.

These are as follows:

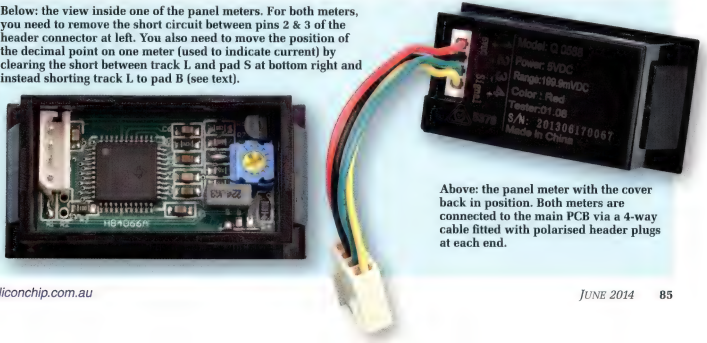
(1) The nine 10µF 25V SMD input bypass capacitors for the switchmode section should be replaced with nine 4.7µF 50V capacitors (ie, identical to those used in the output filter bank). You could use 10µF 50V capacitors instead, to maintain the same capacitance but we don't think this is necessary.

(2) The 100µF 25V input bypass capacitor for REG1 should be replaced with a 47µF 50V/63V electrolytic capacitor.

(3) Zener diode ZD2 should be changed to a higher voltage type. The recommended value to use is 39V however with the above example (ie, running from a 24V lead-acid battery), 33V would also be an acceptable choice.

While REG1 will run hotter with a higher input voltage, under load the switchmode section will likely run somewhat cooler (due to the lower input current) and it may be able to supply a little more current at higher output voltages than would be available with a regulated 24V DC input.

Below: the view inside one of the panel meters. For both meters, you need to remove the short circuit between pins 2 & 3 of the header connector at left. You also need to move the position of the decimal point on one meter (used to indicate current) by clearing the short between track L and pad S at bottom right and instead shorting track L to pad B (see text).



Above: the panel meter with the cover back in position. Both meters are connected to the main PCB via a 4-way cable fitted with polarised header plugs at each end.

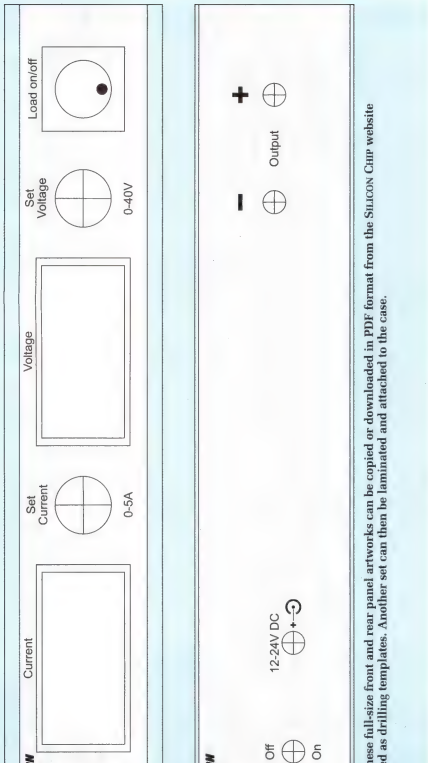


Fig.8: these full-size front and rear panel artworks can be copied or downloaded in PDF format from the SILICON CHIP website and used as drilling templates. Another set can then be laminated and attached to the case.

the metal flange which retains each pin in the block so that you can slide them out.

Connecting VR1 & VR2

VR1 and VR2 need to be connected to the board in order to test it. You can temporarily fit two 10kΩ 9mm linear potentiometers if you have these on hand; there are pads to do so and this is quite convenient but expensive if you have to purchase them. The alternative is to wire up the chassis-mount pots you intend to use with the unit and use them off-board.

The 10-turn types generally have three solder lugs arranged front-to-back, with the two on the pot body being the ends of the track and the one at the rear the wiper. However, this isn't necessarily a standard so you really do need to measure the resistance between the terminals to determine which is which. Basically, with the pot fully anti-clockwise, there should be minimum resistance between the left-most and centre pins on CON5 & CON6.

The most convenient way to wire the pots up is to get cables with 3-way female headers on the end, chop them in half and solder the bare ends to the pot, however this does mean that the plugs can go into CON5 and CON6 either way around so it would be easy to accidentally reverse the action of one or both pots.

A better but more laborious approach is to make up cables using ribbon cable or light-duty hookup wire with a polarised plug on the end, as described above for the panel meters but with three wires this time.

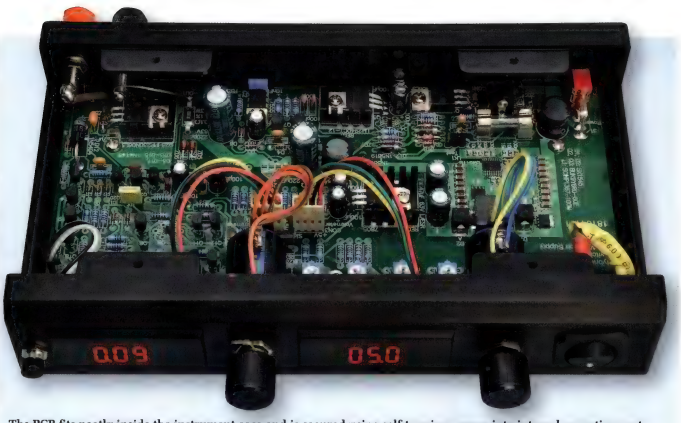
Initial checks

Having wired up VR1 and VR2, turn them both full anti-clockwise. Fit LK2 but leave the shorting block off LK1 entirely. With S1 off (up), connect a 12-24V power supply to CON1 and measure the current drain. You can do this by leaving F1 out and connecting a DMM in amps mode across the two fuse clips. There may be a small pulse of current when power is first applied but this should quickly drop to just a few microamps after a second or so; ie, the DMM should read zero unless set on a low current range.

Assuming that's OK, switch on S1 and check the new current reading. It should be just under 100mA. If it's over 200mA or unstable, switch off and check for faults (eg, incorrectly orientated parts, bad solder joints, etc).

If the current reading is acceptable, you can then check some voltages. The mounting screws of Q1, REG1 and REG2 make convenient ground points (ie, for the black probe).

These voltages should be as follows: bottom-most pin of REG1 = 11.6V to 12.4V (nominal 12V); top-most pin of REG2 = 4.8V to 5.2V (nominal 5V); either end of the 10Ω resistor above



The PCB fits neatly inside the instrument case and is secured using self-tapping screws into integral mounting posts. Be sure to modify the supplied panel meters as described in the text.

D5 = approximately -10V; bottom-most pin of REG3 = -4.8V to -5.2V; left-most lead of the 470Ω resistor below VR4 = -2.5V.

Once you have finished these checks, switch off S1 and disconnect the supply. If any of the voltages were wrong, check the circuitry around the regulators and IC2.

Note that with the power switch on and LK1 out, the output of the switch-mode regulator section will be pulled negative by the boost supply charge pump but it should be clamped by D16 to a safe level of no lower than -0.3V, to protect IC1.

Assuming all is OK so far, with the power off, fit LK1 in the "TEST" position, then switch back on. Check the supply current; it should now be stable at around 150mA. Turn VR2 clockwise, perhaps 10% of the way through its rotation, then adjust VR1 and monitor the output voltage (ie, between the -OUT and +OUT terminals).

The output should change as VR1 is rotated and be fairly stable up to the input supply voltage, at which point rotating VR1 further clockwise will have little effect. Note that the supply current will drop somewhat when the output is 'pegged'. If VR1 doesn't seem to do anything, try turning VR2 clockwise a bit, as the current limit has not been trimmed yet.

You can now plug in the panel meters and check that they operate correctly. Start with the volt meter and check that its reading can be adjusted with VR1; note that it won't be accurate though, we have yet to trim it. You may notice REG1 and REG2 getting warm with the panel meter connected as it draws a fair bit of current (around 130mA).

You can also now connect the ammeter and check that you don't have the meters mixed up, ie, it should have two decimal places rather than one. But note that it will only read zero because (a) there is no load and (b) S2 is not connected yet. If you really want to check it out, you can short pins 1 & 3 of the header for S2 and then check that you can adjust it through a range of (roughly) 0-5A with VR2.

Final tests

Now to finally check that it's all working properly. First, switch off and remove power, then switch LK2 over to the "RUN" position. Adjust VR1 to minimum and VR2 a little above minimum.

If possible, connect a pair of DMMs or a scope to monitor the voltage across D16 as well as the voltage at the output. You may want to insert the 10A fuse now, if you haven't already. If you have a third DMM to measure the amps, connect it across the fuse clips but make sure it's in amps mode (not milliamps).

Re-apply power with S1 off and then switch on. If possible, check the current drain. Without the panel meters connected it should settle at around 120mA but with the meters connected it will be closer to 400mA. There should be around 1.2V across D16 (the minimum output of the switch-mode regulator) and close to 0V at the output.

Now turn VR1 clockwise slowly.

Part List Errata

In the parts list last month, we specified 8 x BC547 transistors and 12 x BC557 transistors. While these would seem to have a sufficient voltage rating (45V for a 40V supply), due to the boosted voltage rails, some transistors may be damaged during operation at high output voltages. As such, we suggest all constructors substitute BC546/BC556 transistors respectively for maximum reliability.

Also, we omitted a 200mm length of 10mm diameter heatshrink tubing.

Can The Supply Be Used As A Battery Charger?

In short, yes, this supply can be used for charging batteries which use a constant current/constant voltage charge cycle. This includes Lithium Ion (Li-Ion), Lithium Polymer (Li-Po), Lithium Iron Phosphate ($LeFePO_4$) and (with some manual input) lead-acid batteries including sealed/gel cells (SLA) and absorbed glass mat (AGM).

Essentially, all you need to do is set the supply's output voltage to the charge termination voltage for your battery pack, set the current limit as high as you can within the capability of the battery itself, connect the supply's output to the battery terminals and turn the load switch on.

The supply will then attempt to pull the battery's terminal voltage up to the set voltage. If it can't, it will deliver the amount of current you have requested until the voltage rises to the set point, then it will keep it there indefinitely. Caution should be used with lead-acid batteries since generally the maximum voltage that can be applied permanently is around 13.8V (slightly higher for SLA).

Higher voltages

Higher voltages can be used with lead-acid batteries for more rapid charging; up to about 14.4V for wet cell and 15V for SLA. But the supply can't be left on permanently; the cells will begin to gas once they reach this voltage and the battery will be damaged if this continues for a long time. Typically, you would switch the supply off once the charge current has dropped to about 10% of the set level, or 30-60 minutes after the maximum voltage has been reached.

While no damage should occur if the supply's input power is interrupted (or switched off) with the battery connected and the load switch on, the supply will draw some current from the battery. Therefore, once the battery has finished charging, turn the load switch off before shutting down the supply entirely.

This current is approximately 8-16mA, depending on battery voltage. This flows from the battery, through Q23's body diode and into the output capacitor bank of the switchmode supply. The linear regulator automatically shuts down when the -5V rail is not present so relatively little current will flow in this condition. However, it may eventually flatten a battery left connected.

As before, the output voltage should increase but the reading across D16 should also increase at the same time, remaining about 0.7V above the output. You should also now find that you are able to turn the output voltage up above the input supply voltage. But do not turn it up much past 40V; we haven't set the maximum voltage yet and this may be possible.

Of course, in theory, the circuitry should limit the output to a safe level but it's best not to test your luck.

If you've gotten this far, chances are everything is working properly but before putting it in the case, it's probably a good idea to do a load test and check that the current limiting operates correctly. For this, you will need to solder a length of tinned copper wire into the "-OUT" terminal (you can re-use this wire later to connect it to the binding post).

Having done that, use clip leads to connect a 5W resistor of say 10-100Ω between -OUT and +OUT (the easiest way to connect to +OUT at the moment is to clip on to the cathode of D13). Next, turn VR1 and VR2 fully anticlockwise and switch the power back on, then advance VR1 clockwise – the current meter should still read (near) zero. You can then rotate VR2 and check that the current flow increases linearly.

Check that the unit is able to supply at least a couple of amps but note that the resistor may get quite hot as you turn the voltage and current up. When you're satisfied it's working properly, switch the power off.

Calibration

The next step is to adjust the trimpots. This includes VR3-VR6 on the main board and either VR7/VR8 (if fitted) or the calibration pots on the panel meters.

First, set the output voltage range. Turn VR1 fully anti-clockwise and VR2 to about halfway. Measure the voltage across the outputs with a DMM and adjust VR4 for 0V. Now turn VR3 anticlockwise, then rotate VR1 fully clockwise and adjust VR3 for 40V.

These controls should not interact but you can re-check the zero voltage setting if desired. Now adjust VR1 for a non-zero output voltage (5V say), VR2 fully anti-clockwise and wind VR6 all the way anti-clockwise, then slowly advance VR6 until the output voltage returns to the set voltage.

That done, connect a DMM set to read amps across the output. The current flow should be low (a few milliamps). Turn VR5 fully anti-clockwise and then advance VR2 fully clockwise. Adjust VR5 to get a reading of 5A, then disconnect the multimeter (don't take too long on this step).

To calibrate the voltmeter, set the supply for a 40V output and adjust VR7 or its onboard pot until that is what it reads. For the ammeter, connect a DMM in amps mode across the outputs as before, dial in a couple of amps and then adjust VR8 or the ammeter pot until the readings match.

Case preparation

The case for this project is a 1U half-rack plastic case; Altronics part number H4996. However, Altronics have produced a special variation of this case, which has two rectangular cut-outs on the front panel for a pair of their 3.5-digit Q0588 LED Digital Voltmeters, which are supplied with it. They also supply and install an SPST rocker switch.

The catalog number for this half-rack case with the two panel meters and the mains switch is K3205. It's available at the special price of $59.50.

Since the case will be supplied with these parts already installed, all you have to do on the front panel is drill the extra holes for the two pots and current limit view pushbutton switch. There are four holes required on the rear panel, for the DC input socket, power switch and output binding posts.

Front & rear panel artwork is provided in Fig.8 and these labels can be attached to the front and back of the case to aid in operation. These diagrams can also be used as a guide for drilling the front panel holes. The front panel hole locations aren't especially critical but for the sake of neatness, it's best to position them where shown.

The rear panel hole locations do need to be accurate however, as the DC input and switch holes must line up with the components mounted on the PCB. The binding posts holes can be

moved if required but be careful that the internal portion of the posts won't interfere with Q23's heatsink fins. We haven't placed them the usual 19mm apart for this reason but depending on how far your binding posts project into the case, you may be able to move them closer together.

Drill each hole with a small pilot drill then enlarge to them size using either a series of larger drills or a tapered reamer. Remove any swarf using a deburring tool or oversize drill bit. If you want to attach labels to the front and rear panels, do so now, after cutting out the matching holes.

Putting it together

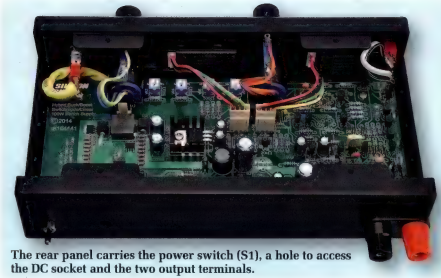
Before proceeding, disassemble the case so that you have four separate pieces – front, back, top and bottom. Don't lose the screws.

Having already soldered leads to the pots, you can now mount them on the front panel and attach the knobs. It's a good idea to terminate the wires with polarised headers so that they can't be plugged in the wrong way around. The wiring diagram (Fig.7) in Pt.2 last month showed how our unit was wired but your pots may have different connections so check these first.

Similarly, solder wires terminated in a 3-pin female header plug to the pushbutton before fitting it to the front panel and pushing the cap on. That done, having prepared the panel meters earlier, pop them back into their plastic housings and clip them into the front panel. Remember that they are configured differently; the meter with track L shorted to pad B (ie, the one you changed) is the ammeter and this goes between VR2 and S2.

There is one more thing to do before putting the board in the case and that is to make up a cable to connect the output to the load switch. Cut two lengths of extra-heavy-duty hookup wire, 240mm and 260mm long. Strip about 6mm of insulation from each end of both wires and crimp a 6.4mm female spade connector onto one end of each wire.

Now place them side-by-side in a 200mm length of 10mm diameter heatshrink tubing so that there is about 10mm between the base of each spade connector and the end of the tube, then shrink it down. Solder the free end of the shorter wire to the +OUT terminal on the PCB (near Q23). The other, longer wire can then pass through the adjacent hole and short stick out the top of the board by about 30mm. Strip this end back a bit further, leaving around 15mm of bare copper strands.



The rear panel carries the power switch (S1), a hole to access the DC socket and the two output terminals.

Now secure the PCB to the bottom of the case using four No.4 x 6mm self-tapping screws; don't use longer screws or they could damage the case. While doing this, you will need to make sure that the heavy-duty wire runs diagonally under the board to emerge near the opposite corner and that the wires sit side-by-side and avoid any posts or protrusions, otherwise it will be difficult to screw the board down.

Push the crimp connectors onto S1's terminals (either way around), then fit the front panel to the bottom of the case using the self-tapping black screws removed earlier. With that in place you can plug in the two panel meters, the two pots and S2. Pay careful attention to the orientation of any connectors that aren't keyed, especially that for S2.

This requires you to determine the pushbutton switch's common, normally open and normally closed terminals. That's done by setting a DMM on continuity mode and finding the two terminals which are shorted when it is not pressed (COM & NC). You then press the button and the two that are shorted must be COM & NO. You can then plug its connector into the header with the COM, NO & NC connections as shown on the PCB overlay diagram.

Rear panel connections

Now fit the binding posts to the rear panel, making sure their wire entry holes are aligned vertically and that their nuts are done up tight. That done, slip the rear panel over S1 (enlarge the hole if it doesn't fit) and secure it to the base but don't use the supplied screws; use two black M3 x 5mm machine screws instead. The supplied screws are too long and would interfere with projections from the bottom of the PCB.

Check that a standard DC connector will pass through the remaining hole and mate with the socket on the board; if not, remove the panel and enlarge that hole. You can then wrap the bare ends of the hookup wire attached earlier around the red (+) output binding post and solder it in place.

For the negative output terminal, loop a short section of tinned copper wire around it, solder it in place, then pass this down through the -OUT pad and solder it there. If you need to remove the PCB from the case in future (eg, to troubleshoot it) then you will need to desolder the binding post connections.

Finally, check that the fuse is in place, You can then fire the supply up for a final operational check. It's a good idea to wind the voltage and current knobs down to minimum before powering up and to monitor the input current initially. However, assuming all the earlier tests were OK, as long as the chassis wiring is correct, it should operate correctly.

Check that it works by varying the output voltage and current and perhaps connecting a testing load. It's then just a matter of fitting the lid using the screws you kept from earlier and the supply is complete. SC

Vintage Radio

By Kevin Poulter

The story of the RCA VoltOhmyst

The first AWA VoltOhmyst (VTVM), the model A56010, was released in late 1953. This example is in outstanding original condition and is shown with a rare AWA RC Bridge which operates as an independent instrument. Note that Sato (Japan) knobs soon replaced the AWA domestic radio knobs, which were prone to breakage, as by then AWA had stopped making them in Bakelite.

If you are interested in collecting vintage radios, you will no doubt have an interest in the multimeters which were used in the 1950s and 1960s. Two models were very highly regarded, the Avometer AVO 8 and the VoltOhmyst, a vacuum tube voltmeter made by RCA in America and Amalgamated Wireless (Australasia) Ltd in Australia.

BACK IN THE 1950s and 1960s, there were two multimeters which were regarded as the "ones to have". One was the British-made Avometer, model AVO 8. This was a large and bulky unit with two range selector switches and a large moving coil meter movement with a "mirror backed" scale.

This was a highly respected unit but it had sensitivity of "only" 20,000 ohms/volt. Now we realise that in these days of cheap, precise digital multimeters, any talk about sensitivity in terms of "ohms per volt" is probably gobbledegook to many readers but in the days before transistors, this was crucial stuff.

To explain, sensitivity, expressed in terms of "ohms per volt" indicated the loading on the circuit being measured with a multimeter set to read volts. For example, if such a multimeter was set to the 10V range, its loading would be 10 x 20,000Ω = 200kΩ. Or as another example, if set on a 3V range, the loading would be 60kΩ. This "loading" means that the multimeter draws significant current from the circuit being measured.

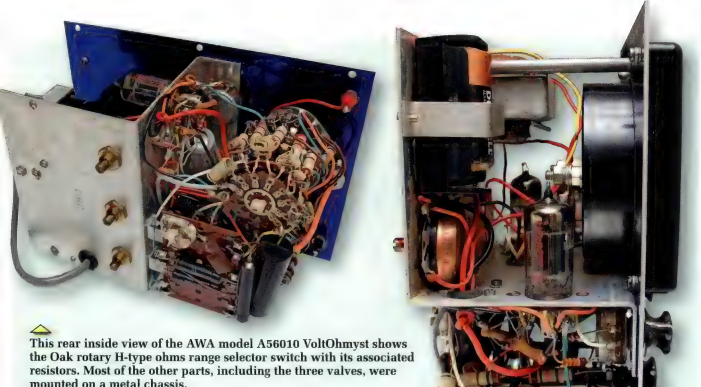
This in turn means that the measured voltage is lower than the actual voltage in the circuit and the error can be quite considerable, depending on whether the circuit is a high impedance one or not. Furthermore, the amount of loading caused by the multimeter may even stop the circuit from working properly and that could mean that the measured voltage is way off the mark.

The basic sensitivity of these analog meters was a function of the current drawn by the moving coil meter. In the case of a multimeter with a sensitivity of 20,000 ohms/volt, the moving coil meter would draw 50μA when the pointer was fully deflected, ie, full-scale deflection (FSD). Earlier multimeters were much worse in this regard because they used a 1mA meter movement and the resulting DC sensitivity was only 1000 ohms/volt.

As good as the AVO 8 Avometer was, its meter loading was a considerable problem when measuring voltages in high-impedance circuits and that applied especially to valve circuits; transistors were only just being introduced and in any case, transistor circuits typically employed lower impedance circuits (ie, they used lower value resistors). But then there was the other highly regarded multimeter at the time, the VoltOhmyst, made by RCA (Radio Corporation of America). This was a VTVM, which stood for "vacuum tube voltmeter".

The VoltOhmyst had two major advantages over the Avometer. One was better sensitivity and the second was its ability to measure peak-to-peak voltages which was to become important for servicing TV sets.

Because the VoltOhmyst was a vacuum tube voltmeter, sensitivity was no longer an issue. It had an input impedance of 11MΩ on all DC voltage ranges, from 1.5V to 1.5kV (in seven



This rear inside view of the AWA model A56010 VoltOhmyst shows the Oak rotary H-type ohms range selector switch with its associated resistors. Most of the other parts, including the three valves, were mounted on a metal chassis.

The side view shows most of the key components, including a very leaky battery (a battery was necessary for resistance readings). Note the resistors with the unusual pink end bands. Also known as "salmon band" resistors, type 108 made by Erie, these were high-stability types, able to maintain their value over varying temperatures for long periods of time.

ranges). This meant that circuit loading was negligible in virtually every measurement application, with the possible exception of directly measuring grid voltages in valve circuits.

While many readers may know about the RCA VoltOhmyst, a lot of people would not be aware that it was also made under licence in Australia by AWA Ltd. Indeed, over the years that the VoltOhmyst was made in Australia, there were two broad versions, both of which are featured in this article.

The first was the AWA A56010 which was a fairly tall instrument with a black Bakelite meter movement. The second was the AWA 1A56074 VoltOhmyst and it measured 172mm high, 180mm wide and 100mm deep, not including the knobs and leather carrying handle. The meter movement itself was 178mm wide, making it easily the largest meter in widespread use at the time. It had up to 11 scales for measuring resistance, DC voltage and AC RMS and peak-to-peak voltages.

The model A56010 measured current but later models did not, unlike the Avometer and most analog mul-

Abbreviated Specifications

Plus or minus DC Volts and AC RMS volts:
(1) 0-1.5V (on separate LO scale for AC), 0-5V, 0-15V, 0-50V, 0-150V, 0-500V, 0-1500V
(2) AC volts and Peak-to-Peak (can be read simultaneously with sinewave RMS values on separate scale): 0-4.2V (on separate LO scale), 0-14V, 0-42V, 0-140V, 0-420V, 0-1400V, 0-4200V

Current: 0-1.5mA, 0-5mA, 0-15mA, 0-50mA, 0-150mA, 0-500mA, 0-1500mA

Ohms (meter calibrated to 0-1,000 ohms): R x1, R x10, R x100, R x1000, R x10,000, R x100,000, R x1MΩ

Accuracy (all ranges): ±3% of FSD

Frequency response, with crystal diode probe type 2R56020: within ±1dB from 50Hz to 250MHz

Maximum input voltage:
(1) Pure DC (no AC components), using DC probe 1R56020 – 1500V, or using the optional High Voltage probe 2R56020 – 30,000V.
(2) AC (no DC components), sinusoidal RMS =1500V, peak to peak sine = 4200V, or peak to peak complex waveforms = 2100V.

Meter Sensitivity: 200 microamps for FSD

Power Supply: 240VAC 50-60Hz, single phase, 5.5W (approx).

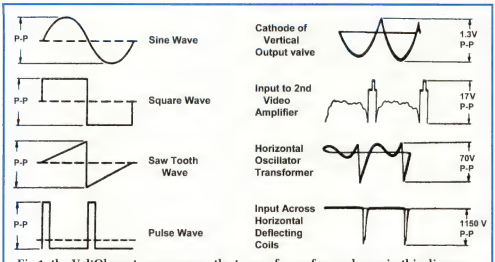


Fig.1: the VoltOhmyst can measure the types of waveforms shown in this diagram and can handle inputs up to 4200V for sinusoidal and symmetrical waveforms.

timeters of the time (note: the AWA A56010 did have current ranges).

All the components were made in Australia, including the impressive meter movement which was manufactured by Master Instruments Pty Ltd in Sydney. That company is still going strong.

Some of the later models also had a mirror section on the meter (such as the RCA WV-98C Senior VoltOhmyst also pictured in this article) by which you could to make sure you had no parallax error when making readings. The idea was that you viewed the meter "square on" so that the meter's knife-edge pointer and its reflection were directly in line. While it is a nice idea, the idea of taking such exact meter readings was a bit futile, considering that the overall meter accuracy was ±3% of full scale reading – a pretty good standard at the time.

To put that in perspective, if you were measuring a voltage of 10V on the 15V range, the best accuracy you could expect was 10V ±0.45V, with the 0.45V being 3% of 15V, the FSD value of the range. Compare that with the 0.1% DC accuracy of today's cheap digital multimeters!

With the ability to read positive and negative DC voltages, DC current, resistances and AC voltage, the VoltOhmyst could also measure sinusoidal and complex waveforms. As noted above, the meter's scales were calibrated to read peak-to-peak values directly and also RMS for sinusoidal waveforms. The maximum input for non-symmetrical waveforms was 2100V and this limit was extended to 4200V for sinusoidal and symmetrical waveforms (see Fig.1).

Circuit description

Fig.2 is a simplified circuit of the AWA A56010 VoltOhmyst with two valves shown, a 12AU7 twin triode (V3) and a 6AL5 twin diode (V1). The two triodes are arranged in what was referred to as a "DC bridge", probably because of the similarity of the arrangement to a Wheatstone Bridge, the classic potentiometer circuit used for precise measurement of voltages.

These days, we recognise the circuit as a simple differential amplifier, with the meter movement connected between the plates of the two triodes. When the currents through the two triodes are equal, the voltage at each plate is also equal and so no current flows through the meter. Feeding a positive voltage to be measured to the grid of triode V3a causes its plate voltage to fall, as more current flows through its plate load resistor. The difference in voltage between the two plates then causes current to flow in the meter movement, deflecting the pointer up the scale.

One of the advantages of such a bridge circuit, or differential amplifier, is that it can respond equally well to negative DC voltages. Of course, the meter movement itself could not respond because its pointer would simply "peg" against the zero stop but that was taken care of by double-pole switching the meter movement to reverse its polarity. To our knowledge, no other multimeter at the time could directly provide readings of negative voltages; you had to change the meter probes around to do that.

When you first turned the meter on, the valves took a few minutes to warm up and reach stable operation. The bridge circuit then had to be adjusted using the zero adjustment control on the front panel. This ensured that the cathode currents (and plate voltages) in both triode sections of V3 were equal and the microammeter connected between the anodes read zero.

Furthermore, the zero adjustment

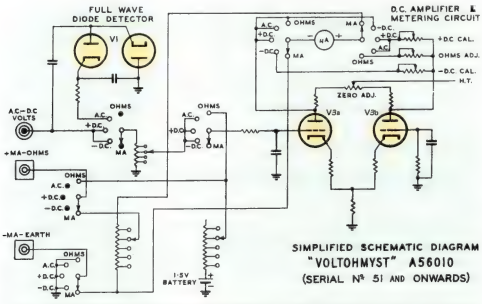


Fig.2: this simplified schematic clearly shows the bridge circuit, based on a 12AU7 twin triode (V3a & V3b). The Zero Adjustment control needed to be set every time the instrument was switched on, after the valve had warmed up and stabilised.

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CUSTOM 4 Custom programs - Charge | Discharge | Recondition | Wait & repeat

	Battery Voltage Range	Charge/Discharge current (per station)	Max Charge Power (per station)	Max Discharge Power (per station)
C7200 (40 watts)	1.2V to 15.0V	up to 4.0A	40 watts	35 watts
C7400 (80 watts)	1.2V to 15.0V	up to 4.0A	55 watts	35 watts
C740ER (170 watts)	1.2V to 36.0V(5.5ton)	up to 6.0A	75 watts	75 watts

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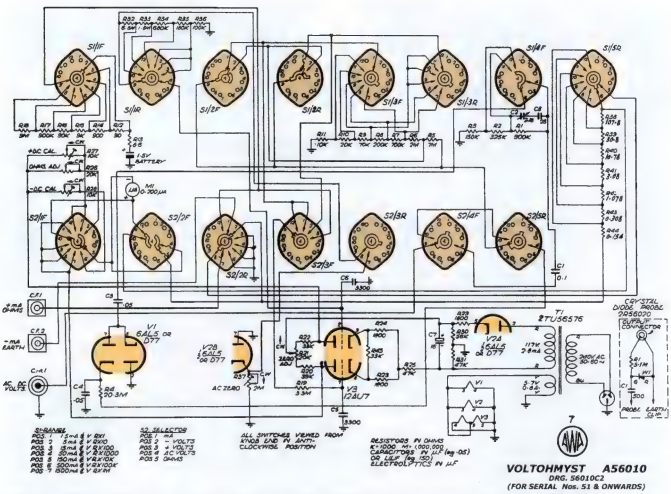

Fig.3: the AWA VoltOhmyst was made under licence from the RCA and was based on the American model, so its circuit is quite similar. In fact, the circuit used in these instruments 10 years later was nearly identical to the original, proof that the design stood the test of time.

control on the front panel could also be used to set the pointer at mid-scale or "centre zero". This allowed the meter to directly respond to positive or negative voltages, although there was no centre-zero scale.

When used as a milliammeter, the function switch disconnects the bridge and changes to the "mA-Ohms +" input terminal. The "-mA" terminal is disconnected from earth.

The AWA unit could test for resistance above 1000MΩ when used with an external DC voltage between 20V and 500V. AC ranges up to 500V could be displayed when measuring from a source impedance of approximately 100Ω. Frequency compensation provided a flat characteristic from 30Hz to 2.5MHz. Adding the crystal diode probe reduced the input capacitance to a low value and the AC voltage ranges were accurate to within ±10% from 50Hz to 250MHz.

Important Safety Notices

(A) The high voltage probe has an earthed guard-ring in front of the hand position. It's vital that the operator's hand is behind this guard-ring in case there's a flash-over, so the current will pass only to the guard-ring.

(B) Do not use the instrument for measurement of AC at power points or the like, if the Active lead cannot be distinguished. The frame of the instrument is earthed via the 3-core mains cable and incorrect application of the test prods would result in short circuit of the supply.

(C) When measuring an AC or DC voltage which has one side earthed, be careful to apply the earthy prod to the earth side of the voltage.

(D) There are many other cautions in the instruction manual, some well-known to vintage radio enthusiasts. For example, short out any large capacitors before measuring resistance values or making any adjustments to the circuit being tested. It's very advisable to read all the AWA warning notes.

Restoration

The AWA A56010 unit featured here had not operated for many years and when switched on after photography, was found to only partially work. A VTVM is easier to restore than a radio, is great to have in the workshop and I've seen one sold for $20 with handbook, so it's a top contender for a restoration project. Many in-home service technicians relied entirely on their VTVM, rather than carrying a bulky CRO to service calls.

Restoration does require attention

The RCA WV-98C Senior VoltOhmyst (left) had a mirror section on the meter, so that the user could eliminate parallax errors when making readings. Later versions of the AWA VoltOhmyst were almost identical to the RCA models.

Below & below right: inside a later model AWA VoltOhmyst. The chassis of this particular unit has been badly corroded by a leaking electrolytic capacitor.

to detail, to ensure it maintains the accurate readings it was designed for. A quick evaluation was initially made to see what was required for a full restoration. This involved checking the valves and capacitors and doing a close physical inspection.

The 1.5V battery was a mess. There's no such thing as a leak-proof dry battery, so consider using a rechargeable battery. I've never heard of a rechargeable that leaked and they are very affordable.

After replacing the battery, all looked good, so power was applied. One of the valve's heaters was not glowing and gently rocking the valves in their sockets showed that the pins were no longer making a reliable connection, so the sockets were cleaned using contact cleaner. It's also a good idea to use contact cleaner on the switch contacts and to check that its body doesn't twist when operated.

If it does, carefully tighten the two assembly bolts that run the entire length. But here's an important caution: there's a delicate balance between "securely tightened in place" and "snapping the wafers"!

The unit I had didn't have the original AWA domestic radio knobs, yet they looked factory installed. Fellow

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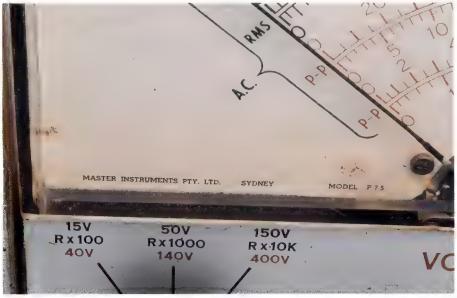
This photo shows the range of standard and optional probes that were available for the AWA A56010. They are, clockwise from bottom right: the optional 2R56020 high-voltage probe for measurement up to 30,000V DC; an earth cable with alligator clip; standard leads for resistance and current measurements, a "Direct Probe" with two accessory slip-on probes (DC probe and crystal diode probe); the "Standard Probes"; and (in the centre) another earth clip.



All the parts for the later-model AWA VoltOhmyst were made in Australia, including the impressive meter movement which was manufactured by Master Instruments Pty Ltd in Sydney (who still advertise in SILICON CHIP).

HRSA member and AWA Archivist, John McIlwaine explained that the constant switching tended to break the AWA radio knobs, as by that time AWA no longer made them in Bakelite. So Sato Bakelite knobs were sourced from Japan instead.

Design upgrades

The 1964 RCA Senior VoltOhmyst WV-98C was nearly identical to the AWA 1A56074 model shown here, even using the same valves. However, one 6AL5 in the power supply was replaced by a selenium rectifier, rated at 130V @ 30mA. This instrument boasted an input resistance of 11MΩ.

A couple of concerns with the USA model: even though the power supply was earthed, the mains supply was via a 2-pin plug, so no supply earth was connected, plus the mains on/off was via a wafer switch. By contrast, the AWA version was fitted with a 3-core mains plug and was connected to Earth.

References: www.aaa1.biz/SC/vtvm.html SC

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Voice Recorder will not restart

I purchased the Enhanced 45-Second Voice Recorder (SILICON CHIP, December 2007) about 12 months ago, after reading the article in EPE magazine here in the UK. I have built it and used it as a "voice box" in an animated Father Christmas we have in our Christmas display. I am using the recorder as a "tape recorder" ie, both links 1 & 2 out.

The system works well, incrementing through the messages with each pulse to ME1 (which is provided by a noise/voice or hand-clap detector) but after completing the 12th message it does not restart again at the first message. Is it possible to get the recorded messages 1-8 to cycle in a continuous loop or have I missed something?

Keep up the good practical electronics work and great shared articles with EPE. (J. S., Pontefract, UK).

- To make the Voice Recorder operate in 'tape' mode, links LK2 and LK3 should both be in position rather than 'out'. Link 1 is only for enabling or disabling the 'beeps'.

Getting the HK828 recorder chip to automatically 'rewind' at the end of the memory is a little tricky, mainly because the manufacturer's data is rather confusing in this regard. It should be achieved by connecting the 'M7 enable-bar' screw terminal (connected to pin 8 of the HK828) to the 'Chip Enable-bar' terminal (connected to pin 23 of the HK828), using a short length of wire.

This will hopefully work because the M7 enable-bar pin goes low when the HK828 reaches the end of its memory, and pulling the CE-bar line low resets the HK828 to 'start again'.

Links query on Stereo Headphone Amplifier

While constructing the Stereo Headphone Amplifier (SILICON CHIP, September & October 2011) I noticed a small issue which has not appeared in your Notes & Errata. The construction details in the October 2011 issue suggest to start by installing 10 wire links. The PCB supplied by SILICON CHIP has eight of those links as tracks on the PCB. The only required links that I could identify are two in the upper left corner of the board and these are indicated by dotted lines on the screen printing.

I thought you might like to include this in future Notes & Errata. There also appears to be a small error in the parts list. Six 10Ω resistors are listed but I can only find four on the circuit and four locations on the board. (B. D., via email).

- The top side links on the double-side plated-through PCB are provided as a convenience, so you don't have to fit them yourself. Two links have been omitted from the top layer plating and as you say, they do need to be installed. This has been done on purpose since if you use the board to build the Tiny Tim stereo amplifier (SILICON CHIP, November & December 2013), these links must be omitted.

There are actually six 10Ω resistors – two inside the L3/L4 coils (to reduce their Q), two near IC1 and the others are near Q7 & Q19. Maybe you missed the ones that go inside the coils as this is a somewhat unusual place to put them (but convenient for the PCB layout).

USB/RS-232 connector query

Why have you used a USB type-B connection in the USB/RS-232 interface project? This is unfamiliar to me and is unlike any of the many spare USB cables that I have. (D. C., via email).

- The reason we used a USB type-B connector on the 'PC' side of the interface is that this makes it possible to hook it up to the PC using a standard 'type-A to type-B' cable, as used for many other peripherals like printers, scanners and so on.

Since the interface behaves like a

UHF Mains Switch Is Reluctant To Work

I have built the UHF Mains Switch as described in the February 2008 edition and I am having an issue with the transmitter. I was becoming concerned with the intermittent switching success rate and found that the transmitter LED was giving a strange indication.

When the unit hasn't been used for a couple of hours and the on button is pressed, I get a rapid lighting of the LED (an error condition?). After half a dozen or so applications I eventually get the solid 'on' indication and the switch switches. I can then switch the unit on and off and it will work like a charm (until I leave it for an hour or so, then the problem has returned).

If I press both on and off switches together I get the 3-blink error condition as described in the article. I measured the 9V at 9.4V. Any ideas as to what could be wrong? (S. A., via email).

- It seems that the power is not latching on via transistor Q1, after S1 is pressed. Check that the collector of Q2 goes close to 0V when S1 is pressed and that the voltage between base and emitter of Q1 is about 0.6V. Also the voltage between the emitter and collector of Q1 should be low, at around 0.2V when S1 is pressed.

You may have a dry solder joint somewhere. The rapid flashing of LED1 would indicate the 5V power supply is erratic. In other words it is varying rapidly over a wide range.

Odd Behaviour From LED Ammeter

Some years ago, about 2008, I built the automotive LED Ammeter featured in January 1999 for use on my 1983 Honda CB1100F motorcycle. I am using the ammeter with a display consisting of four red LEDs, two yellow LEDs and four green LEDs. I have adjusted the range to be approximately -10A to +10A and adjusted the centre to light up one of the yellow LEDs at zero amps. I love it!

Initially, the ammeter performed very well indeed and behaved exactly as described in the article but more recently, over the past two or three years, its behaviour has changed. I don't know if this is the ammeter changing characteristics or something else on the bike changing.

For example, I might install a brand new AGM battery fully charged and will calibrate the ammeter to show a reading in the centre (yellow LED) once I am certain that the charging system has brought the battery up to full charge, following the starting drain. Then, over the course of several weeks to a couple of months, the ammeter will gradually drift downward towards the red end.

I am fairly certain that the charging system is not changing its behaviour but I cannot be certain. If I readjust the ammeter's centre point, the drift toward red continues until ultimately I run out of adjustment range on the pot. I built a replacement ammeter using new components and the very same circuit and it also drifts over the same period of time.

I have also replaced batteries in this bike more often than most other owners have done. I consider myself lucky to get three years out of a new AGM battery. But the ammeter behaves the same way with each new battery I install.

I have not made any changes to other charging system components, but I believe them to be in proper working order. Whenever I check the readings of the ammeter against a regular analog ammeter into the same circuit, I get consistent results.

So what I am trying to sort out is whether there is something going on with the ammeter or is it with the battery or the charging system? Can you think of any reason why the ammeter itself might be doing this? How would you recommend I modify the circuit if I wanted to increase the range of the pot shown in the original circuit as VR2?

By the way, if I interpret the circuit description properly, VR1 can be thought of as a way to adjust the full-scale range of the ammeter and VR2 can be considered the centre adjustment. Is this correct? Any light you can shed on this would be terrific. (P. S., via email).

- VR1 is the actual full-scale adjustment and VR2 is for the centre zero adjustment, as you state. You can increase the range of the centre zero adjustment by changing the 22kΩ resistor between pins 6 and 7 of IC1 to a larger value.

You have proven the drift is not in the LED ammeter itself since another ammeter does the same. We would suspect the connection between the battery negative lead to the chassis is causing the problem. Since the LED ammeter is measuring the voltage drop across this, any change in its resistance will affect the reading.

Try cleaning up the chassis connection of the battery lead. There also may be a poor connection between the battery lead and connector.

standard peripheral device as far as the PC's USB host controller is concerned, this is the most appropriate approach.

Antenna connection for portable DAB+ radio

I have purchased a portable or personal DAB+ radio (with no speaker) and I want to connect it to my home amplifier. When I do this, the reception on the DAB+ radio drops out or is non-existent.

It works fine with the earplugs that came with the unit but as soon as I plug it into any amplifier, reception drops out.

I understand that the ear plugs are part of the antenna but when I unplug the line cable from the amplifier at the amplifier end or switch the amplifier off, the signal on the DAB+ comes straight back. I have looked through the back issues of your magazine but can't seem to find anything relevant. (G. H., via email).

- We published a Circuit Notebook item in the September 2005 issue (page 42) for an adaptor which gave line output and antenna input for pocket radios. All of these radios use the shield of the headphone cable as the antenna circuit. The adaptor circuit uses an RLC network to isolate the antenna signal and extract it from a separate 75-ohm whip antenna. It should work with your personal DAB+ radio.

NiMH cells for power tools

My B&D hedge trimmer's Nicad battery pack has had it and to buy a replacement would have cost over $100. I checked with Jaycar for replacement sub-C cells and a set of 15 of these would cost me about $80. So I went on-line and bought 16 6Ah sub-C cells from Hong Kong for $A26, including delivery. The original battery pack was 1.8Ah so it is looking good at this point from a usage perspective.

My question regards the charger that came with the trimmer: Will it charge the NiMH batteries satisfactorily? I realise that you can't know the details of all chargers/battery packs on the market but can you advise me please?

I checked your article search and found the Li-Po battery article from October 2013 but is this relevant for me? (I. S., via email).

- The main reason why drill battery packs fail is that the supplied charger does not do a good job of charging them. Over-charging is common and most chargers do not have any means of sensing the end-of-charge point.

Have a look at our articles on this subject in the December 2006 issue. One covers repacking the battery pack and the other describes a charger controller, based on a PIC microcontroller. We can supply the PCB and programmed micro for the project.

Transistor query on headphone amplifier

I am building one of your hifi stereo headphone amplifier projects. Your

LC Meter Won't Measure Bigger Capacitors

I built the LC Meter described in the May 2008 issue from the kit sold by Altronics. However, it won't measure any capacitor larger than 39nF and it is baulky about giving a reading on anything over 15nF; it gives the over range message. This is a long way short of the 800nF limit in the specifications.

To make a long story short, I diagnosed a reluctance by the oscillator built around comparator 1 on the PIC chip to continue to oscillate when the larger capacitors are connected for testing. I am connecting the capacitors directly to the pins on the small supplied adaptor PCB that clamps under the test terminals. I measure the oscillator frequency using a frequency counter at pin 18 of the PIC.

The basic frequencies F1 and F2 used by the meter are measured as 520kHz and 367kHz. F2 is very close to the expected 71% of F1. According to a calculation, F1 should be 503kHz.

I account for the difference by the capacitors in the meter being somewhat low, though still within 10% tolerance. In an effort to find my problem I put in a pair of matched capacitors within 20pF of each other for C1 & C2 but that wasn't the problem.

I made a list of my test capacitors and put them through the L, C and F formula using 100µH for L and the test capacitor value for C. Then I measured the actual frequency of the oscillator with each test capacitor connected. The measurements were as expected but as I said, the oscillator seems to stop and the meter tells me over-range when I connect anything over 15nF. When I see over-range I get a random changing frequency readout below 1000Hz.

I don't have an oscilloscope so I can't tell if there is any sort of waveform there. Sometimes it will start again after a short time and the meter then displays the expected value for the capacitor but mostly it will not restart. Above 39nF it will never restart.

I have unsoldered and resoldered every joint, checked all components for value and position on the PCB, and checked all polarised capacitors for polarity. The only anomaly is the 10µF electro at pin 17 of PIC; apparently the inverting input of comparator 1. The diagram says 10µF 25V. Altronics supplied 35V. I searched the SILICON CHIP website for any Notes & Errata or references to problems with this design but found nothing.

I'm stumped and I don't want to blindly fiddle with the parts on the beautiful PCB in a comparatively costly kit. I'm wondering if the moulded axial lead 100µH choke supplied is a low-Q example of the breed. I've heard that small moulded chokes aren't that marvellous. I've also heard that large capacitance compared to the inductance in a resonant circuit will depress the overall Q of the combination.

So what if it was low-Q to start with and gets worse the more capacitance you add? But I'm not an engineer and I have no formal education in electronics. (P. H., Mackay, Qld).

● We haven't heard of this problem before with the LC Meter and as you have discovered, we have not needed to publish any Notes or Errata for this project as yet. As far as we are aware, there were no errors.

It does sound as if the oscillator in your unit is unwilling to oscillate with larger values of capacitance and all we can suggest at present is that either (a) the 100µH RF choke in your unit is somehow very low in Q, as you suggest; or (b) the PIC16F628A in your unit is slightly faulty, in terms of its gain in the comparator.

We suggest that you substitute another 100µH inductor to see if that fixes the problem. If there is no improvement, obtain a new PIC-16F628A and send it to us so we can program it with the firmware (or we can supply one at the usual price).

article specifies BC559 transistors. I seem to have acquired BC559 'C' versions which I believe are the high-gain versions.

Does this matter? Or should I try and acquire the lower gain non-C (B?) versions? (P. T., via email).

● It won't matter. In fact the 'C' version (which is indeed high-gain) is slightly better since using these will maximise open-loop gain and thus provide the best distortion cancellation. We used BC549C/559C transistors to build at least some of the prototypes.

In circuits where high transistor gain could be a problem, we usually reduce the gain by means of a resistor or capacitor, which has the additional benefit of making the transfer function more linear. For example, we've done this in the input pair with emitter degeneration resistors and in the VAS transistor with a Miller capacitor.

Hearing aids are too expensive

I long have struggled with a severe high-frequency loss and a friend passed me your articles on the Blamey & Saunders hearing aids (SILICON CHIP July 2011 and March 2013). I have also monitored the Blamey & Saunders site for a couple of years. I was most impressed that you apparently found you could listen to the TV and car audio at 'normal' volume levels that are comfortable to others. Is this correct?

The reason for my question is that I have had several hearing tests in recent years and all except one audiologist wanted to commit me to buy hearing aids ranging from $6000 to $8000, without me trying them out to see if they worked. One local Canberra company did agree. I had to pay for the fitting and the consultation – and I could trial them for a month.

But I was disappointed. I could not hear the TV or car audio any better (road noise in the car was terrible) and the only advantage I could pick was that I could hear the birds tweeting. I still struggled to hear my softly-spoken wife.

The final straw of my trial was when I put my hand to one ear when out and about and one unit was missing. It turned out that I had left it at home. I returned the units, much to the dismay of the vendor.

I use cordless headphones for the TV. Do your B&S aids eliminate the need for this and can you use them in a moving car? It really annoys me that

very expensive products that do not work (for me, at least) are so widely promoted.

Finally, I did hear that some people cannot get a real benefit from even hi-tech aids and I might be in this category. I would greatly appreciate your thoughts on my issues (G. H. via email).

● Ross Tester replies: I have found that I can listen to radio, TV etc at what is a 'normal' level for my partner. In fact, if I don't have the hearing aids in she complains that I have turned the TV up too far! But even more importantly, I find that my comprehension level is very much improved when wearing the hearing aids.

I find that many TV channels (particularly Foxtel "lifestyle" programs and for some reason, the UK-originated ones) and some radio stations sound severely 'muffled' without hearing aids. Again, my partner was sick of me continually asking "waddidhesay?"

I'm not saying I have perfect hearing with the hearing aids in but it is a significant improvement. You will almost certainly find road noise is amplified to the point of annoyance with hearing aids – and you won't believe how loud a traffic indicator click is!

You'll also quickly find every squeak and rattle in your car that you didn't know existed before. That's a cross I'm more than willing to bear for the sake of better hearing of everything else. I simply turn the hearing aids down (not off) when in the car.

I'm not sure why anyone with high-frequency hearing loss wouldn't get *some* improvement at least. Perhaps those who reported no improvement were expecting too much. As far as I am concerned, the hearing aids are good but they are not miracle workers!

The fact that you can tailor the response yourself using the supplied software is also a bonus; no need to pay an audiologist to do it for you.

The newer (digital) hearing aids are an improvement over the older types but they are rather more expensive. And as I said in the review, if I hadn't known about the digitals and had been unable to do an A:B comparison, I would have remained quite happy with the analog aids.

Ultrasonic Anti-Fouling Unit Has Bad Transducer

I recently purchased a kit for the Ultrasonic Anti-Fouling Unit (SILICON CHIP, September & November 2010) from eBay. It came with a potted transducer which was open circuit.

The eBay retailer did send me a replacement transducer but it is also open circuit and therefore blows the circuit board fuse immediately. My faulty potted transducer is model number EY5606 but that does not correlate to the un-potted option model numbers in the Jaycar catalog.

As per the Jaycar specifications, I would expect it to have a resistance of 15Ω across the transducer. Do you agree? (J. F., via email).

● The transducer is a piezoelectric element which should have a measured capacitance of about 3800pF (or 3.8nF). It should be an open circuit as far as an Ohms test is concerned.

The equivalent transducer from Jaycar is Cat. AU-5556. The article on how to encapsulate the transducer was in November 2010. You can purchase the magazine on our website.

Big power supply for a radio linear amplifier

Back in May 1991 SILICON CHIP presented a 13.5V 25A power supply for amateur transceivers. I read with interest the article for the revised Motor Speed Controller presented in the February 2014 issue. It looks good!

Have you thought about adapting that technology to produce a large power supply, similar to that presented in May 1991? My interest is to power an amateur radio linear. It requires around 50-60V at 30A.

I will be actually building four supplies delivering 13.5V at 60A as I have four transformers for this power supply. I will series or parallel them for a universal power supply that will serve as 13.5-52V or so. Each transformer delivers 12V at around 70A. (B. F., via email).

● You are suggesting that the primary of a mains transformer be driven with pulse width modulated power similar to how the Motor Speed Controller (Feb. 2014) adjusts motor speed. This is instead of a Triac chopped mains waveform applied to the primary of the transformer as used in the 13.8V 25A power supply. The mains voltage applied to the transformer primary can effectively be adjusted in level under feedback control so that the transformer secondary delivers the required voltage for a regulated 13.8V after rectification and filtering.

The idea may work but the Motor Speed Controller circuitry would need to be different since it produces a full-wave rectified (DC) output that drives

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Changes To MPPT Charge Controller Not Warranted

I have built 24V versions of the MPPT charger controller (Silicon Chip, March 2012). I made two changes to them. I replaced the first Schottky diode (D1) with an ideal diode circuit using the LTC4357 – see www.linear.com/product/LTC4357

Second, I purchased a coil for inductor L1 instead of making it myself. The coil I bought is a Coilcraft SER2918h-103KL – see http://nl.farnell.com/coilcraft/ser2918h-103kl/inductor-pwr-10uh-28a-0-1-20mhz/dp/2288915?Ntt=2288915

To test it, I installed a 100kΩ resistor instead of the thermistor. The solar panel is a 71-cell type, about 100W peak, and I have also tried using a 230W peak solar panel.

I have a serious problem. When the battery voltage drops below the 23.45V the charger stops charging in the normal way and it starts to charge using short bursts of current, as when the voltage drops below 10.5V (or in my case, 21V) but the bulk charge LED does not blink.

You might think I did not set the voltage at TP1 correctly but that is not the case, because I measured it and because the bulk LED is not blinking.

Can you please help me solve the problem? (G. B., via email).

● It does seem like the charger is operating in the pulse charge low battery voltage mode. This could be because of interference introduced into the PIC (IC1) by your replacement inductor. This should be replaced with the type we used, Jaycar LO-1224, and hand-wound as detailed in the article. The iron-powdered core damps possible high frequency interference which can otherwise affect IC1's operation.

If this does not solve the problem, test the charger using the specified Schottky diode shown in the circuit rather than with the ideal diode circuitry. That should return the circuit to its original form, removing unknown effects that could be caused by your changes.

the motor whereas the transformer would require an AC voltage drive.

Speedo Corrector has intermittent fault

I have fitted two of the Mk.3 Speedo Correctors (Silicon Chip, September 2013) and both show the same fault. The customer complains of an intermittent 5km flick of the speedo needle.

When returned and set up on the bench and set to run at a steady 60km/h this fault is evident. There doesn't seem to be any set period of time when this fault occurs. In fact, watching the speedo you would say it's OK but then there it is – and then the needle holds steady again.

Please advise your thoughts on the problem. (N. Q., via email).

● Since receiving this query, we have discovered that the constructor did not install the 1µF supply decoupling capacitor for IC1. This capacitor connects between pins 5 & 14 of IC1 and is shown on the PCB overlay diagram but unfortunately was not shown on the circuit diagram. (see notes and errata page 104). Installing the capacitor solves the problem.

Solar-powered skylight query

In your January 2013 article on the Solar-Powered Skylight you promised more information on the self-regulating nature of the system but I can't find any. I am interested in designing a smaller version of the same project but I can't find any information on the relationship between the solar panel and the LED clusters. Could you assist me please? (T. B., via email).

● We published an article in the March 2011 issue, on a solar panel simulator which gives a guide to the output characteristic of 40W and 120W solar panels. You can see the relevant graphs on pages 74 & 75 of the March 2011 issue – see www.siliconchip.com.au/Issue/2011/March/12V+20-120W+Solar+Panel+Simulator

You can use these as a guide to outputs of smaller panels. As far as the LEDs clusters are concerned, they tend to behave as a constant voltage load, so they will load down the panel to their normal (ie, LED array) voltage. You need to size the panel so that it cannot deliver more current than the LED array can handle.

Does fan controller cause motor noise?

I have an S&P TD-500/150 inline duct fan, rated at 50W/240V. At present, I use a Triac-based fan speed controller but this produces a loud hum from the motor at low speed. Would the Deluxe Fan Speed Controller from the May 2014 issue run this motor with less hum at low speeds? (D. C., Rotorua, New Zealand).

● With this controller, the motor should be virtually noise-free with the only noise being produced by the gearing and the fan itself.

Battery voltage concern for Champion amplifier

I built a Champion amplifier and preamplifier (Silicon Chip, January 2013) for a friend who needs to operate it from a battery as a low-power guitar

Change-Over Switch For Charge Controller

I built the Battery Charge Controller featured in the April 2008 issue, using an Altonics kit. My question is why not use a change-over switch on link 5/6 so that SLA & wet lead-acid batteries can be charged with the same unit?

Am I missing something? (P. E., Heathcote, Vic).

● Yes, you can use a toggle switch to select between SLA and flooded lead-acid. The same goes for the standard/3-step option. We did not do this on the prototype since not everyone would want the added wiring, cost and complexity with externally switched options.

It is important to make these switch changes for a different battery while the charger is powered down since the selections at LK1-LK6 are only checked at power up.

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amplifier. I also built a trickle-charger from the February 2005 issue and fitted the whole assembly into a small loudspeaker enclosure with an SLA battery. The intent is that the unit will be operated from the battery between charges and should last at least 12 hours on the 1.3Ah battery I have used.

However, when fully charged, the SLA battery is delivering in excess of 13V and the Champion is specified to operate between 9V and 12V. Can you advise if the Champion will continue to operate under these conditions and if not, what would you recommend doing to change it? (B. D., via email).

● The AN7511 chip used in the Champion has an "absolute maximum" operating voltage of 14V with a recommended range of 3.5-13.5V. If you are trickle charging the battery at 13.8V (a typical value), there will be some voltage drop across diode D2 which should keep the AN7511's supply more or less within the recommended range. In other words, we would expect it to receive no more than 13.5V as long as the battery does not go above 13.8V.

If the battery can go above 13.8V or you just want some extra safety margin, you can change diodes D1/D2 (whichever you are using) to a 1N4004 or similar which should drop the voltage by another 0.5V or so. It would also be possible to wire two diodes in series (eg, a second diode in-line with the supply wiring) to drop the voltage further if necessary.

Note that at the high end of its operating voltage range, power output quickly becomes thermally limited so if you want maximum power from the chip, it's best to run the board at less

continued next page

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Ask Silicon Chip

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than 12V; around 9V is ideal. This can be done with a zener diode.

For example, if you leave D1/D2 as originally specified (1N5819) and add a 4.7V zener in series with the positive supply, with its anode to pin 2 of CON8 and its cathode to the battery positive terminal, IC2 should have a supply of around 8.7V.

That will give a continuous power output of around 3W, compared to about 2W with a 12V supply. Note that you would need to use a 5W zener diode (eg, 1N5337) as it will dissipate about 1.8W when the amplifier is delivering maximum power.

For a cheaper solution, you could try putting a 10-12Ω 5W resistor in series with the supply. This will cause the supply voltage to drop as IC2 draws more current, reducing dissipation in IC2 at higher power settings. This may also drop the supply voltage by enough at idle to keep IC2 within its ratings with a 13.8V battery but you'd have to check it.

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Notes & Errata

Speedo Corrector Mk3, September 2013: there should be four 1μF capacitors in the parts list (not three) and the circuit should show a 1μF capacitor between pins 5 & 14 of IC1. The overlay diagram is correct.

Micromite Micrcontroller, May 2014: a new version (Ver 4.5C) of MMBasic for the Micromite is available from the Silicon Chip website. This version fixes a bug which could, in rare cases, cause the Micromite to partially erase its firmware and disable MMBasic when used with some low-cost USB-serial adapters.

Other than that, no new functionality has been added. All but three chips we have supplied have the latest firmware version and those three customers have been notified.

Query on channel component matching

In your various stereo preamp/power amplifier kit designs, do the various kit suppliers go to the trouble of matching components (between channels) when deemed necessary (RIAA equalisation) for example? I've graphically learned this lesson in many of the stereo kits that I've personally built.

Just the other day, I checked the value of the RIAA capacitors in the old Universal Preamplifier kit (Silicon Chip, April 1994) that I'd built some years ago. The capacitor values as measured on my trusty (but reliable) capacitance meter were all over the place so I replaced them with matched sets of the correct values and it has made quite a beneficial difference in terms of equalisation accuracy and stereo image.

I don't recall this point ever being stressed and/or even mentioned in your construction articles. Perhaps in the interests of optimised performance, it should be. My capacitance meter is my most used and valuable bit of test gear for such projects. (F. S., Ingham, Qld).

- Ideally the components in the feedback network (which sets the RIAA equalisation) should be 5% tolerance or better. Most capacitors with a nominal 10% tolerance can be expected to be within 5% (or better) of their nominal value. **SC**

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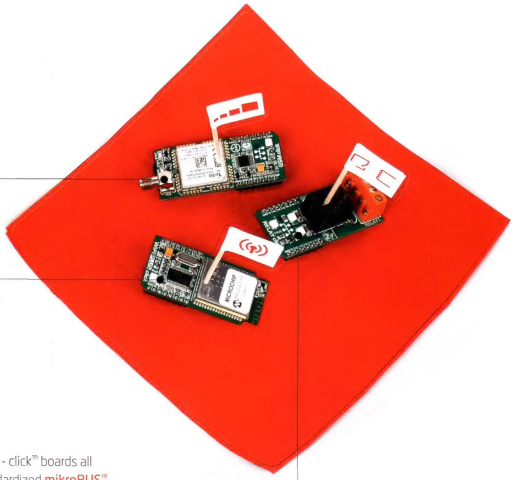

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